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PREFACE

This document is the preliminary version of the GenRad/DSD ADS Reference Manual. All information in this document is subject to change. We will make every effort to provide timely notice of any changes, and further information as it becomes available.

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Section 1
How to Use This Manual

This manual is designed to allow easy access to information needed by the user of the Futuredata Advanced Microprocesser Development System.

Sections Sections are placed in the order of use. The beginning of each section may be found by fanning the manual pages slightly and matching the appropriate black block on the edge of the Table of Contents page with that of the section. Sections of more than three pages are indexed.

Pages Each page has one or two lines across the top. If the page holds information about a command or other input to the AMDS system, there is one line. If the page holds purely explanatory information, there are two lines.

Conventions An explanation of the conventions used to describe commands is given in Section 4.

QUICK INTRODUCTION TO AMDS

For a quick introduction to AMDS features and capabilities, read only the page headings, the information shown under the subheading PURPOSE if that subheading is given, and look at the photographs of the keyboard and the various displays.

Section 2
Introduction to Microprocessor Development

SOFTWARE DEVELOPMENT

The Futuredata Advanced Microprocessor Development System provides all of the software tools necessary for the rapid development of large microcomputer programs. Four major functions of the AMDS are used for software development. These are the Editor, Assembler, Linker, Debugger, and File Manager.

Software development typically proceeds in the following manner. First a program in assembly language (or Basic) is typed into the Editor. The Editor provides a large number of features for easy entry and editing of text. The finished program is then stored on diskette.

Then the Assembler translates the assembly language program on the diskette to binary microprocessor instructions. The Assembler is capable of detecting a number of syntax errors. If there are errors, the program is edited using the Editor and assembled again. The executable binary program is stored on disk.

Often the program is written in modules which may be located anyplace in memory, and which must be linked together. Relocation and linking is performed by the Linker. The linked program is stored on a diskette file.

The program is then executed by the Debugger which provides powerful features for testing. The Debugger displays the contents of memory and the microprocessor registers. Changes can be made where necessary.

Normally there are execution errors in a program when it is first written. After the errors are found using the Debugger, changes are made in the assembly language program using the Editor. The program is assembled, linked and tested again. THis process is repeated if necessary until the program is perfect.

HARDWARE DEVELOPMENT

A hardware prototype is developed using the Emulator, which is provided with a plug which fits directly into a microprocessor socket.

To the prototype, the Emulator appears almost exactly as though a microprocessor were plugged into the socket. However, the keyboard, display, and all of the other features of the AMDS are available to the user during emulation. This makes testing of the prototype extremely efficient.

The prototype clock, interrupts, control lines, direct memory access, I/O, and memory may be tested separately.

Section 3
Beginning Operation

TURNING ON POWER

To begin operation:

1) Plug diskette drive cable into connector on AMDS back panel.

2) Plug in AMDS power line cord.

3) Turn on switch on back panel.

4) Turn on diskette drive unit.

5) Insert system diskette in drive 0. For proper method of insertion see USING DISKETTES on page 3-3.

6) Wait 5 seconds for drive speed to stabilize.

7) Type J{system-character} to begin operation of one of the Futuredata system programs. system-character is one of the following:

M	File Manager
E	Editor
A	Assembler
L	Linker
D	Debugger
U	Utility
B	Basic Interpreter
C	Basic Compiler

TURNING OFF POWER

To turn off power:

1) Remove all diskettes. If a diskette is in the drive when power is turned off, it is possible that the magnetic information stored on the diskette will be changed.

2) Turn off diskette drive unit.

3) Turn off switch on AMDS back panel.

HANDLING DISKETTES

A diskette is a flexible disk coated with magnetic material and enclosed in a plastic jacket. A paper envelope is supplied for storage. Observing the following rules will insure diskette reliability:

1) Never touch the magnetic recording surfaces of the diskette. These surfaces can be seen through the holes punched in the jacket.

2) When a diskette is not loaded in a diskette drive, it should at all times be kept in the envelope provided.

3) Never bend a diskette.

4) Never subject a diskette to magnets or magnetic influence. Diskettes should not be stored near power transformers or motors.

5) Diskettes must be used and stored at a temperature within $50^{o}F$. This is equivalent to $10^{o}C$ to $52^{o}C$.

6) Always insert a diskette into the diskette drive carefully.

7) Do not write on the plastic jacket with a lead pencil or ball-point pen. Use a felt tip pen.

8) Heat and contamination from a carelessly dropped ash can damage a diskette.

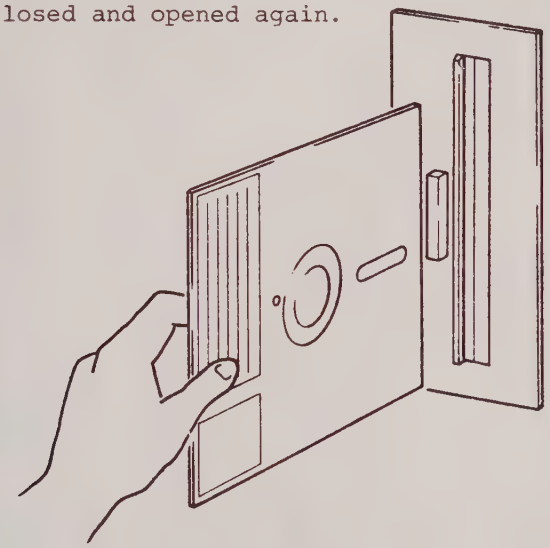
9) Do not expose a diskette to sunlight.

10) Do not attempt to clean the magnetic surface. Abrasions may cause loss of stored data.

INSERTION INTO DRIVE

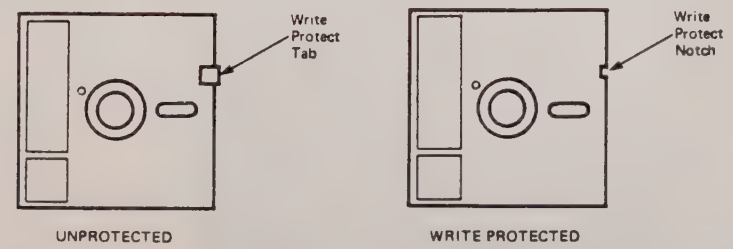
The proper position of insertion is shown in the drawing below. To insert a diskette, depress the drive door latch. Insert the diskette with the label to the right until a click is heard. Close the drive door.

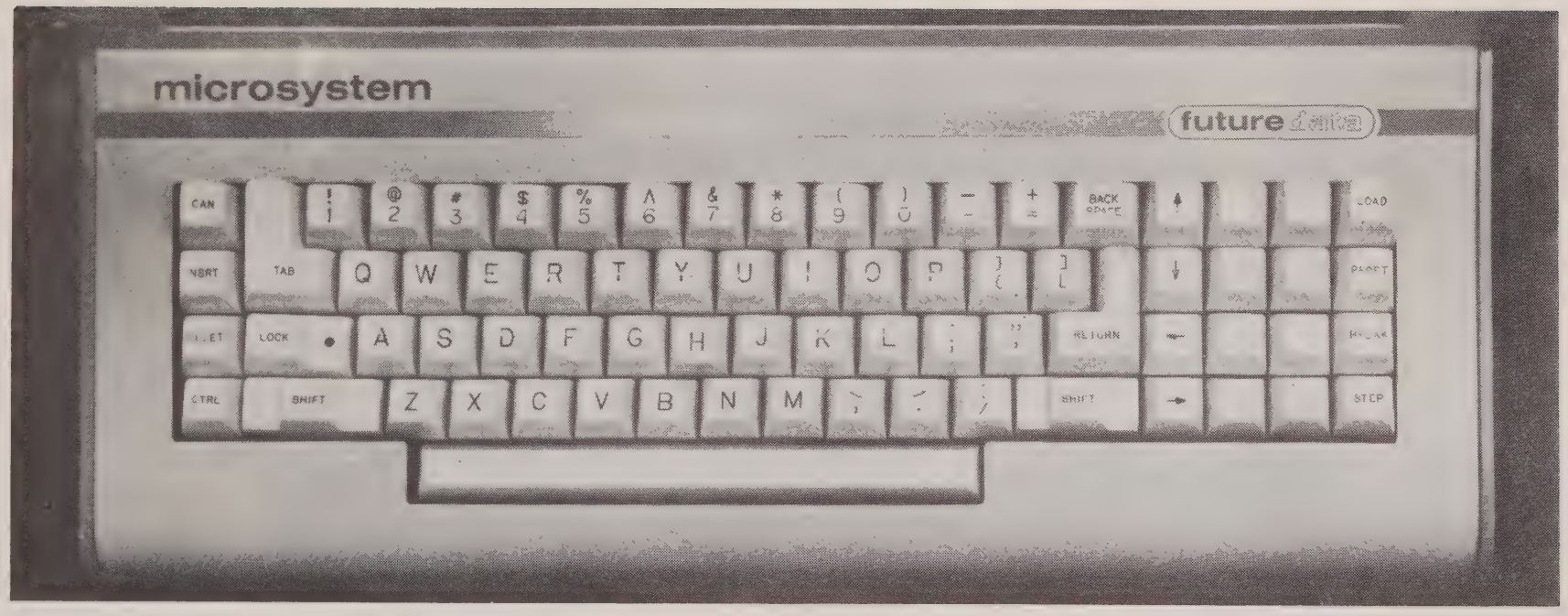
Once the click is heard on insertion, it is not possible to remove the diskette until the door is closed and opened again.



PHYSICAL WRITE PROTECTION

A diskette drive will not write on a diskette which has an open write protection hole or notch. To write magnetic information on a diskette it is necessary to cover the hole or notch with a tab or label. Tabs or labels are supplied with the diskette. The magnetic information on a diskette may be read regardless of write protection. System write protection is also available, see page 6-11.





Futuredata AMDS keyboard The special keys on the left are used in text editing. The arrow keys on the right scroll or space through text (Editor) or memory (Debugger). The keys on the far right are hardware control function keys.

It is important to note that the bracket and brace keys to the right of the P are never used for entering commands. They are only used when they are part of text. Brackets and braces in this manual show only the syntax of commands or required input.

Section 4
Conventions

COMMANDS

All commands and command parameters are printed in Large type. In Sections 8, 9, and 10, Assembler and Linker input is also shown in large type.

Command Letters Command letters, which must be typed exactly as shown, are printed in upper case.

Command Parameters Parameters, which require a choice by the user, are shown in lower case. If a parameter is optional, it is shown in brackets: [parameter] If a parameter is required, it is shown in braces: {required-parameter} Do not type the brackets or braces. They only show syntax and are not part of any command or required input.

Dots in Syntax... A series of dots in a command syntax shows that the parameter previous to the dots may be repeated indefinitely. Vertical dots have the same meaning.

Blank Spaces No blanks are allowed within system commands, and none are shown. Blanks shown for Assembler and Linker input are required.

Special Keys are Shown with Rectangles A rectangle drawn around a letter, series of letters, or a word indicates that a special key must be depressed on the keyboard. The letters shown inside the rectangle are the same as the letters printed on the keytop. Here is an example:

RETURN (depress the return key)

Command Entry After each keyboard input the return key must be depressed to indicate to the system that what was typed is ready to be entered.

FILE NAME CONVENTIONS

Drive Number Prefix In any case where a file name is required as a command parameter or an input, d:, where d is the diskette drive number, must be prefixed to the file name unless the diskette is loaded in drive 0. If the prefix is not given, drive 0 is assumed.

Create File Prefix In any case where the file name of an output file is required as a command parameter or an input, N: (new) may be prefixed to the file name to create the file before writing to it. The create command described on page 6-5 may also be used to create a file, but this command can only be used during File Manager operation, whereas N: may always be used.

Use of Both Prefixes When both prefixes are used, the sequence is:

[N:][d:]file-name

Section 5
Command Files

INTRODUCTION

The AMDS allows the user to save frequently used sequences of commands on a diskette file and later to use this file for command input. Provision is made for accepting input from the keyboard, prompting for input, and for passing parameters to commands when initiating command file operation.

IMPORTANT NOTE

The Assembler and Linker wait for RETURN before accepting input again after operation. A command file must contain a blank line at this point to ensure that these system programs terminate properly.

RETURN FOR ONE LINE

[prompt]^L . . .

prompt will be displayed when Command File processing reaches this line on the diskette file.
Typing [RETURN] causes the AMDS to continue reading commands from the file.

ADDENDUM

prompt must be part of a command. No messages or characters which are not part of a command are allowed in a command file. Characters entered at the keyboard must, when substituted into the line in which the carat L occurred, become part of a legal command. The command may continue after the carat L, and other carat L instructions may be placed in the same line.

RETURN UNTIL ^ IS INPUT

[prompt]^K

prompt will be displayed.
No characters are allowed after the K.

PURPOSE

This command allows input from the keyboard until ^ is typed. The AMDS then continues reading commands from the command file.

ADDENDUM

prompt must be part of a command. It may be absent. No characters which are not part of a command are allowed in a command file.

COMMAND

^{n}

n may be any integer from 1 to 9.

PURPOSE

This sequence within a command in a command file will be replaced by the nth parameter entered at initiation of command file processing.

EXPLANATION

Parameters will replace this sequence by direct substitution. The command in which the sequence occurs will be expanded or contracted to fit the parameter.

INITIATING READING

J^{file-name}[,parameter]. . .

file-name is the name of the file on which commands have been stored.
parameter is a string of characters which will be directly substituted into commands on the file.

PURPOSE

This command causes the AMDS to accept further command input from the file file-name.

EXPLANATION

Reading of this file for command input is terminated when the end of the file is reached, or if command file processing is aborted. Up to 9 parameters may be entered.

ABORTING OPERATION

SHIFT BREAK

Command file processing may be aborted by holding the shift key down while depressing the break key.

NOT A COMMAND FILE

The file specified in a J^file-name command does not have the "C" attribute.

FIRST CHARACTER OF FILE NOT "J"

The first line of a command file must start with a J command.

Section 6
File Manager

INTRODUCTION

The File Manager is a computer program which allows the user to create, delete, and copy diskette files.

A file is any collection of information such as a program, data, or binary computer instructions. Each collection of information is referenced by a file name. A file is first created by executing a command which writes the file name into the diskette file directory and allocates to this file at least one track of the 76 available on the diskette. As information is written to the file, the system automatically allocates additional tracks as needed. One track at a time is added, unless a greater number is specified when the file is created.

BEGINNING FILE MANAGER OPERATION

Enter JM [RETURN] to begin operation.

COMMAND

I[drive-number]

drive-number may be 0 or 1.
drive-number may be omitted; the system will specify drive 1.

PURPOSE

Initialization A diskette must be initialized before it can be used for the first time.

Erasure Initialization erases any information previously stored on a diskette.

EXPLANATION

As supplied by the manufacturer, diskettes have no magnetic information written on them. Initialization causes the boundaries of the tracks which later will hold file information to be defined and formats a file directory. Before initialization begins, the File Manager displays the message: INITIALIZE DISKETTE ON UNIT n? Typing Y (yes) starts initialization. Pressing the RETURN key bypasses initialization.

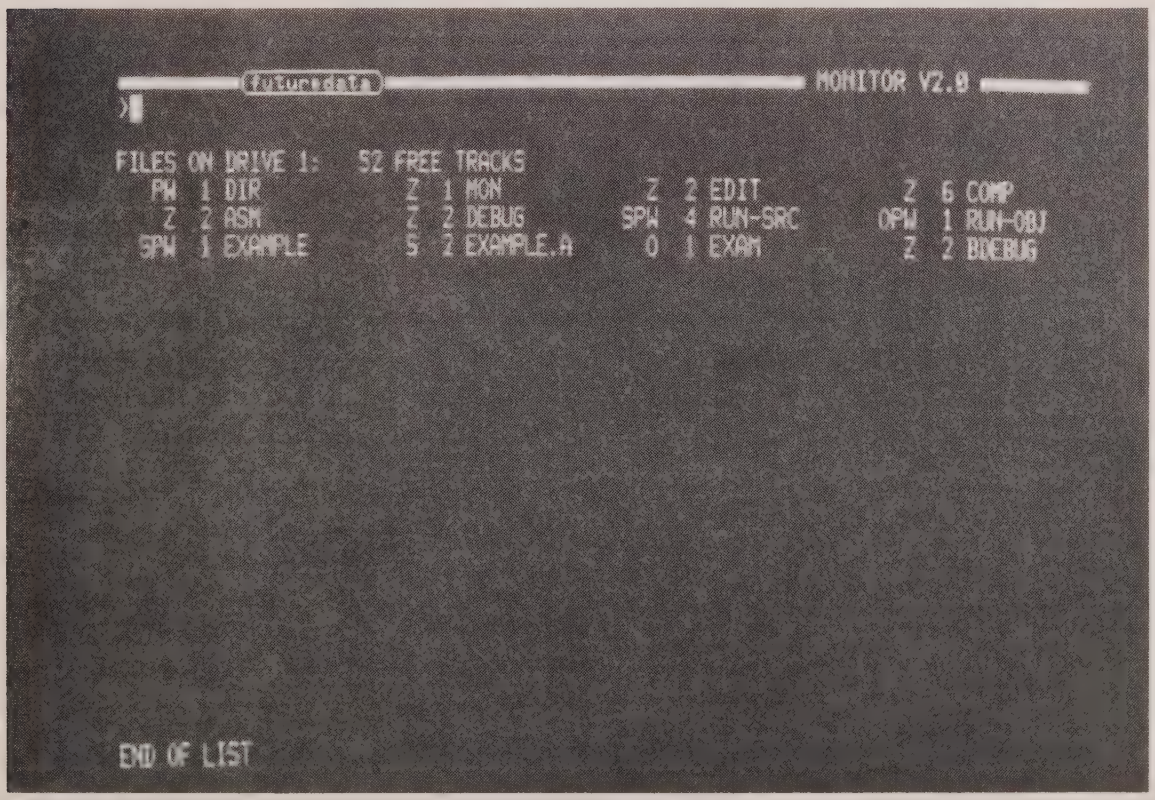
COMMAND

D[drive-number][P]

drive-number may be the integer 0 or 1.
If drive-number is not specified, the value assumed is 0.
If P is appended, the directory will be printed.

PURPOSE

This command displays the file directory information which is on the diskette loaded in the specified diskette drive. Included in the directory display are: 1) the drive number in which the diskette is loaded, 2) file names, 3) file attributes, 4) the number of tracks allocated to each file, 5) the number of tracks on the diskette which have not yet been allocated.



NAME CONVENTIONS

Each collection of information stored on diskette is called a file and is referenced by a file name. The File Manager will accept only names which follow these conventions:

1) File names must be one to ten characters in length.
2) The first character must be a letter or a number. After the first, any other ASCII character which results in a displayed symbol may be used, such as slash, period, or hypehn.
3) No blanks, commas, or colons are allowed within the name.

EXAMPLES

These are legal file names:

A	2
COUNTERS23	Q-B//3
COUNT.R	DATA

COMMAND CONVENTIONS

[N:][drive-number:]{file-name}

N: specifies that the file is to be created.
drive-number: specifies the drive number in which the diskette is loaded. It may be 0 or 1. If this parameter is not included, 0 is assumed.

EXPLANATION

N: and/or drive-number: may be prefixed to a file-name in any command in which a file name is one of the parameters. The usage of N: must be appropriate; the file name it prefices must be one that will be written.

CREATE COMMAND

C{file-name}[,tracks[,extension-size]]

tracks is an integer which specifies the initial number of tracks to be allocated to the newly created file. If omitted, the value used is 1.

extension-size is an integer which specifies the number of tracks which will be added to the total allocation of tracks each time information written to the file overflows the former allocation. If omitted, the value used is 1.

PREFIX CREATE COMMAND

N: prefixed to any new file name specifies that the system will create the file before writing to it. See Command Conventions on the previous page.

SCRATCH FILE COMMAND

S{file-name}

The system will request verification: SCRATCH THIS FILE? Type Y (yes). Pressing the RETURN key causes the command to be ignored.

PURPOSE

This command deletes the file name from the directory and releases the diskette tracks which had been allocated to that file.

The scratch command requires writing to the directory. If the file has the P attribute (permanent) or if the diskette is physically write protected, deletion cannot take place. (See Specify File Attributes Command in this section for information on the P attribute. See Section 3 for further information on physical write protection.)

FREE UNUSED SPACE IN FILE

F{file-name}

PURPOSE

This command releases unused diskette tracks from a file.

EXPLANATION

If new file information is written over the information on an existing file, and the new file information does not require as much space as the overwritten file, the unneeded diskette tracks may be returned to system availability.

RENAME FILE COMMAND

R{current-file-name},{new-file-name}

PURPOSE

This command renames a file, leaving all other information unchanged.

EXCHANGE FILE NAMES COMMAND

E{file-name-one},{file-name-two}

PURPOSE

This command exchanges the names of two files, leaving all other information unchanged.

COMMAND

M{from-file-name},{to-file-name}

M{[d:]from-file-name},{[N:][d: to-file-name} (creates new file)

d is the drive number. It may be 0 or 1.

PURPOSE

Copies (moves) all information stored under from-file-name to the file to-file-name. to-file-name may be prefixed by N: to indicate that it is a new file which must be created. In this case, the new file will be given the same attributes as the "from-file."

d: may be prefixed to any file name to indicate the diskette drive number.

EXAMPLE

```
MFILE-A,N:1:FILE-B
```

This example creates the file FILE-B and copies the information on FILE-A to FILE-B. FILE-B is on diskette drive 1.

```
MFILE-A,N:FILE-B
```

FILE-B is on diskette drive 0.

COMMAND

X{from-drive-number},{to-drive-number}[,type]

drive-number may be 0 or 1.

type may be any one of the following characters:

A copy all files

S copy only files with a Z attribute (system files)

If type is omitted, only files without a Z attribute will be copied.

PURPOSE

This command allows easy bulk copying. It is recommended that at least one copy be made of an important diskette to insure against loss in case the original is damaged or lost.

EXPLANATION

The name of each file is displayed as it is being copied. If a file to be copied already exists on the "to-drive" and has the same name as a file on the "from-drive," the name of the file and the message WRITE INTO EXISTING FILE? will be displayed. Typing Y (yes) authorizes writing over the existing file. Pressing the RETURN key will bypass the copying of that one file.

COMMAND

A{file-name}[,attribute[attribute]...]

attribute may be any combination of the following characters:

Data Type Attributes

- S source file (text)
- C command file (text)
- R relocatable object file (binary)
- O absolute object file (binary)
- Z system file

File Protection Attributes

- P permanent file (cannot be deleted)
- W write-protected file (cannot be overwritten)
- B blind file (not listed in the file directory)

PURPOSE

File attributes help prevent the misuse or accidental destruction of files. Except for a blind file, file attributes are listed in the file directory display; they are a useful bookkeeping aid.

EXPLANATION

Data Type Attributes Data Type Attributes specify the kind of information contained in the file. These are helpful in preventing file misuse. For example, the Assembler will not attempt to assemble a file with attribute R (relocatable object file). Instead, the system will display the message: NOT A SOURCE FILE.

Programs supplied by Futuredata will use only files with the correct attributes, as shown:

Program	Input File Attributes	Output File Attributes
Editor	S	S
Assembler	S	R
Linker	R	O
Debugger	O	
Basic Compiler	S	S
Basic Interpreter	S	
Utility	O or S	any
System		
Command File	C	
Jump Command	Z	

Files may be given multiple data type attributes. For example, if it is necessary to edit a command file it must have the attribute S. To execute a command file it must have the attribute C. If it is given both attributes, the file may be used in both ways without executing a new attribute command. The system does not prevent assigning an inappropriate attribute, such as an S to a binary object file.

File Protection Attributes These attributes prevent the destruction of a file. Also, the blind file attribute helps prevent use by unauthorized persons.

Notice that to prevent deletion of a file and destruction of the information in a file by writing new information over it, it is necessary to use both file attributes P and W.

Blind files are not listed in the File Directory; thus they cannot be used by persons who do not know the name of the file because it is necessary to specify the file name to access a file. The existence of blind files on a diskette can be determined without knowing the name, however. If the number of tracks allocated to files in the directory is less than the number of tracks in use, the difference is the number of tracks allocated to blind files.

FILE NOT FOUND

The requested file was not found on the specified diskette. Either the file does not exist, or an erroneous drive number was specified, or the file name was type incorrectly.

DUPLICATE NAME

The new file name specified for creating or renaming already exists on the specified diskette. Choose another name.

DRIVE NOT READY

The disk drive specified for use is not ready. This message is generated when the referenced drive is unloaded. It will also be generated if a recently loaded drive is referenced before it has come up to speed. This takes approximately 5 to 10 seconds. Wait a few seconds, and try again.

There are several conditions that will prevent a drive from becoming ready for use. Probably the most likely is that the diskette is inserted incorrectly or is defective. If this message is generated even when a new diskette is used, it is possible that there is a hardware fault.

PERM FILE

The file referenced for deletion has the permanent "P" attribute and cannot be deleted. If the attribute is changed, it can then be deleted.

WRITE PROTECT

A file has been selected for output that has the write protect "W" attribute. The file may be read from, but not written into. If rewriting is necessary, change the file attributes.

DISK FULL

This message is generated when space is requested

and none is available on the diskette. The message may occur when a new file is being created, or when more space is required while writing into an existing file. The space should be obtained on another diskette or by deleting superfluous files on the full diskette.

NOT SOURCE FILE

This message is generated when a file without the source "S" attribute is specified as a file to be read by one of the system functions that require source file input.

NOT OBJECT FILE

This message is generated when a file without the object "O" attribute is specified as a file to be ready by one of the system functions that require object file input.

PARM ERR

When displayed after a "J" command, this message indicates that the requested function could not be found on the system diskette. This message usually occurs when there was an invalid parameter character.

PERM I/O ERR

A permanent error has been detected. During a seek or read, the system retries the operation 10 times before the message is generated. During a write, the system rereads the data to see that it was written successfully. If this read is unsuccessful, the write followed by read check is also retried 10 times.

The message is most likely caused by a worn or defective diskette. If it persists after trying several ndw diskettes, it may be a hardware problem.

END-FILE

A read operation has attempted to read beyond the end-of-file.

The following messages may be generated only when the user program call the Disk I/O routines directly:

PARM ERR

A specification error was detected in the parameter list passed to the Disk I/O routine.

FILE NOT OPEN

A function was attempted on a file that is not open.

Section 7
Text Editor

INTRODUCTION

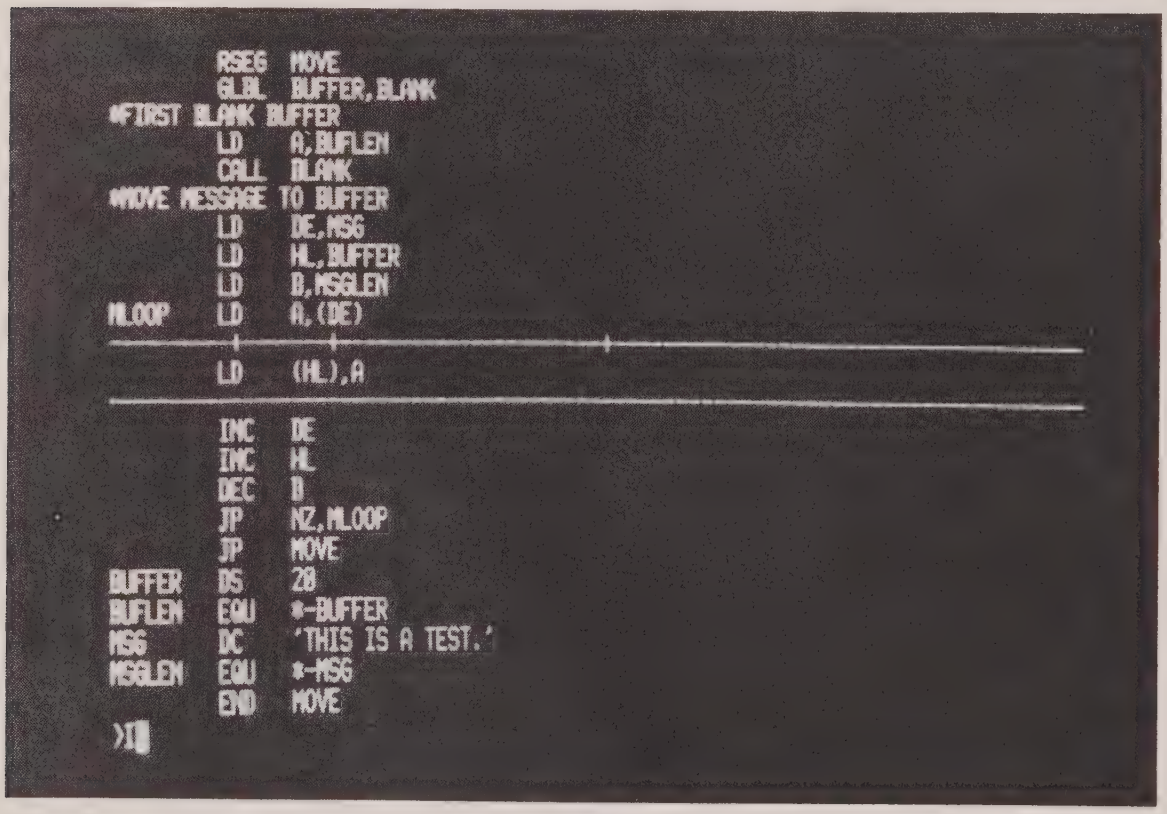
The text Editor is a computer program which allows easy creation and correction of files of text. Examples of text include command files and computer instructions in Assembly language or Basic.

BEGINNING EDITOR OPERATION

Enter JE RETURN to begin editor operation. The display will then show two dashed lines across the center.

DISPLAY EXAMPLE

This is an example of an Editor display which has been filled with text, in this case part of an assembly language program:



Notice that the cursor is on the command line. This indicates that the Editor is ready to accept commands.

There are always two dashed lines across the display during Editor operation. These are a visual guide to the line used for text entry and editing (edit line).

Tab Line The dashed line just above the center of the display is called the tab line. Vertical lines (+'s) on the tab line show the position of tab stops. Tabs are set at positions 10, 18 and 42 automatically upon entering the Editor. These positions are convenient for entry of assembly language mnemonics. (Tabs may be set or cleared using the T commands.)

Edit Line The center line of the display, which is between the two dashed lines, is the edit line. All text entry and editing is done on this line.

Entry Cursor The entry cursor is a blinking rectangle. This cursor is present at the command line during entry of commands and at the edit line during entry of text. The cursor is positioned at the bottom of the display when the Editor expects a command as the next entry at the keyboard. The cursor is positioned on the edit line when the Editor expects text as the next entry at the keyboard.

Command Line The command line is at the extreme bottom of the display. When the entry cursor (the blinking rectangle) is positioned on this line, commands to the Editor may be entered.

Message Line This line is the second from the bottom of the display and is just above the command line. When an error is made in the entry of a command, an error message appears here. Some Editor commands request verification on this line. If there is no message, this line will be blank or contain text.

Workspace The workspace is a part of computer memory which holds more than a thousand lines of text (with 48K memory). The text may have been read from a diskette file or entered at the keyboard.

Display There is a special definition of the display during Editor operation: The display is that part of the workspace which is visible.

The display is 24 lines high and 80 characters wide. Twenty-one lines of text are visible, and 3 lines are used for tab, dashed visual guide lines, and commands. Messages to the user temporarily overwrite the bottom text line.

Input File, Output File The Editor retains file names so that once they have been specified in commands, they need not be included again.

COMMAND

L [file-name]

If file-name is omitted, text will be loaded from the input file previously specified in an L command.

PURPOSE

This command causes the workspace area of computer memory to be loaded with text from the input file.

If a file name is specified, that file then becomes the new Input file. When an L command without file name is executed, the Editor uses the last specified Input file.

EXPLANATION

The first 11 lines of the loaded text will be immediately visible on the display. Other area of the workspace can be viewed using commands described later.

Information stored on the Input file is not altered.

The first time an L command is executed, text is loaded starting at the beginning of the file and continuing until the workspace is full or the end of the file is reached.

Second and subsequent executions of the L command load the workspace starting at the line after the last line loaded during the previous execution.

If an attempt is made to load into the workspace after the end of the file has been reached, the message END FILE is displayed.

COMMAND

W[$][*][file-name]

If file-name is not specified, text will be written to the output file previously specified in a W command.

If the file file-name has not yet been created, it is necessary to create it by prefixing the file name with the characters N:

If $ is specified, only that part of the workspace from the beginning up to but not including the text entry line will be written to the output file.

If * is specified, the text which was written to the output file will not be removed from the workspace.

Both $ and * may be used in the same command, only in the order shown.

PURPOSE

This command writes the workspace to the output file.

EXPLANATION

If a file name is specified, that file then becomes the new output file used when an output command is executed without specifying a file name. The command can also cause an output file to be created.

When a new output file is specified, the system displays the message: END OUTPUT FILE? The user must type Y (yes) to end the old output file and begin with the new file as the output file.

COMMAND

N

Both input and output filenames must have been previously specified.

PURPOSE

This command is the equivalent of a W command followed by an L command.

The entire workspace is written to the previously specified output file and completely removed from the workspace. Then the workspace is filled from the previously specified input file.

End Output File (E) — Editor

COMMAND

E

PURPOSE

This command terminates use of the present output file.

DISPLAY

The Editor is in the command mode when the blinking cursor is on the command line (at the bottom of the display).

If a command is entered in error, a message is written on the error line above the command line.

EXPLANATION

See the Keyboard Editing Operations table on Page 7-13 for an explanation of command mode editing features.

COMMAND

I RETURN	Enter Line Insert Mode
RETURN RETURN	Leave Line Insert Mode

PURPOSE

This command allows entry of text to the workspace.

EXPLANATION

Execution of this command allows entry of a new line of text between the edit line present before execution and the line above the edit line.

At execution, the edit line present before execution and all the lines below it in the workspace are pushed down one line; the edit line is then blank. Characters may then be entered to the edit line at the keyboard.

At the end of entry of the new line, the RETURN key is depressed and the entire process described above is repeated.

Two successive depressions of the RETURN key, with no keystrokes in between, cause the Editor to leave the text entry mode; the Editor is then ready to accept a new command.

The character insert sub-mode may be entered from this mode by depressing the INSRT key.

See the Keyboard Editing Operations table on Page 7-13 for an explanation of editing features.

COMMAND

X [RETURN] Enter line editing mode

[RETURN] Leave line editing mode

PURPOSE

Text may be edited efficiently in this mode.

EXPLANATION

This command moves the blinking cursor to the edit line to enable editing that line. The character insert sub-mode may be entered from the mode by depressing the [INSRT] key. The scrolling keys [↑] and [↓] may be used in line editing mode to move other lines to the edit line. The cursor does not move during scrolling.

See the Keyboard Editing Operations table on Page 7-13 for an explanation of editing features.

COMMAND

INSRT Depressing this key turns this mode on or off.

PURPOSE

Characters may be inserted or deleted using this sub-mode without re-typing the rest of the line.

EXPLANATION

The Editor is in Character Insert Sub-mode when there is an asterisk on the dashed line below the edit line.

This sub-mode may be used in either the Line Insert Mode (I) or the Line Editing Mode (X).

See the Keyboard Editing Operations table on Page 7-13 for an explanation of editing features.

Mode: Command	Line Insert (I)	Line Edit (X)	Character Insert (a submode, works with line insert and line edit modes)
DELET (delete) — Removes character under cursor and all of line to right of cursor.	Removes character above cursor and moves all of line to right of cursor one space left.	same as Line Insert.	same as Line Insert.
CAN (cancel) — Removes entire line.	same	same	same
↑ ↓ — Scrolls text, blanks command line.	Returns Editor to command mode.	Scrolls text, cursor remains on edit line.	Leave character insert mode, scroll text.
RETURN — Enters command.	Depressing RETURN key twice causes Editor to leave line insert mode and returns to command mode.	Editor leaves line editing mode, returns to command mode.	Editor leaves character insert mode. Continues in line insert or line edit mode.
← → — Spaces cursor right or left, does not affect text.	same	same	same
SPACE — Enters a blank under blinking cursor, moves cursor right one space.	same	same	Moves cursor, character under cursor, and all of line to right of cursor one space right. Inserts blank at former cursor position.
BACKSPACE — Moves cursor left one space, removes character under cursor.	same	same	Removes character to left of cursor. Cursor and all of line to right of cursor move one space left. Adds blank in right end of line.
other — Enters character corresponding to key.	same	same	Moves cursor, character under cursor, and all of line to right. Inserts character corresponding to key at former cursor position.

ADVANCE TEXT KEY

Each depression of this key advances the text one line.

ADVANCED TEXT COMMAND

An

n is the number of lines to advance. The number must be less than 256.
A$ advances the text to the end of the workspace.

BACK UP TEXT KEY

Each depression of this key backs up the text one line.

BACKUP TEXT COMMAND

Bn

n is the number of lines to backup. The number must be less than 256.
B$ backs up the text to the beginning of the workspace.

EXPLANATION

The following comparison explains the use of the words "advance" and "back up." Compare the workspace to a very long sheet of paper with the text typed on it. Compare the display to a small window which is in front of one area of the paper.

As the text is advanced, the paper is moved upward, and the section which can be seen through the window is closer to the end of the text.

As the text is backed up, the paper is moved downward and the section which can be seen is closer to the beginning of the text.

COMMAND

F[{delim}{string}{delim}[{rstring}{delim}[A][V]]]

delim is any character occuring in neither string nor rstring

string is any series of display characters, including blanks.

If string is not specified, the previously specified string is used.

A (all) specifies that all matches of string from the current edit line to the end of workspace be replaced.

V (verify) specifies that the system ask for verification before replacing a string. Type Y to replace, RETURN to continue without replacing, and N to terminate the F command.

PURPOSE

This command searches for a match between string and a character or series of characters in the workspace. The command may display the first line found containing a match. Also, it may replace the characters string with rstring in the first line or all lines containing a match.

EXPLANATION

Finding a String When this command is used to find a string of characters in workspace, searching begins on the first line following the current edit line. The first line in which a match occurs is displayed. Since the parameters of the previous F command are saved, subsequent searches may be initiated merely by executing the command F RETURN. After a line is displayed, it is possible to enter the line edit mode (X command) and change the text on the edit line or any of the surrounding lines.

Finding and Replacing a String When this command is used to replace a string of characters, searching begins on the current edit line. If A (all) is specified, searching and replacing continues to the end of workspace.

It is possible to use this command to delete characters from lines in workspace. This is done by specifying a null replacement string by typing the second and third delimiters with no intervening characters or spaces. This causes the characters in string to be deleted. The characters after string.

EXAMPLES

These are legal F commands:

```
F
F/OLDSTRING TO BE DISPLAYED/
F*BAD*GOOD*AV
```

Notice that the command

```
F.TEST.
```

would find two matches in the line:

```
THIS IS A TEST OF THE FITTEST.
```

Not only would the command find the word TEST, it would also match the last syllable of FITTEST. This can be prevented by specifying a string with blanks on both sides:

```
R. TEST .
```

This command would match only occurrences of the word TEST.

COMMAND

G[{delim}{string}{delim}[{rstring}{delim}[A][V]]]

delim is any character occurring in neither string nor rstring
string is any series of display characters, including blanks.
If string is not specified, the previously specified string is used.
A (all) specified that all matches of string from the current edit line to the end of the Input file be replaced.
V (verify) specifies that the system ask for verification before replacing a string. Type Y to replace, RETURN to continue without replacing, and N to terminate execution of the G command.

PURPOSE

This command searches for a match between string and a character or series of characters in the workspace and Input file. The command may display the first line found containing a match. Also, it may replace the characters string with rstring in the first line or in all lines containing a match.

EXPLANATION

The G (Get) command is identical to the F command except that it searches both the workspace and the Input file. Searching begins as in the F command. If the end of the workspace is reached during a search, all the text in the workspace is written to the Output file, the workspace is filled again with text from the Input file, and the search continues until a match between the text and the string is found or the end of the Input file is reached.

Except for the field of search, the explanation of the F command applies to the G command.

DELETE LINES COMMAND

DEL n

If n is not specified, only the edit line is deleted. n must be less than 256.

PURPOSE

This command deletes the edit line and n-1 lines beneath the edit line toward the end of the workspace.

CLEAR WORKSPACE COMMAND

CLR

PURPOSE

This command clears the display and all of the computer memory devoted to workspace.

SET TABS COMMAND

T{column-number}[,column-number]. . .

Column-number is an integer between 1 and 80 inclusive. If column-number is not specified, all tabs are cleared.

PURPOSE

This command sets tabs to which the cursor will be advanced when the tab key is depressed.

EXPLANATION

Each tab stop appears as a + symbol on the tab line. If the Tab key is depressed when the cursor is at or past the last tab stop, the cursor will appear at the first character on the line.

CLEAR TABS COMMAND

T

PURPOSE

The T command without parameters clears all tabs.

EXPLANATION

It is not possible to clear fewer than all the tabs.

COMMANDS

SU

SL

PURPOSE

The SU command causes all keyboard alphabetic entries to be entered as upper case only, even though the shift key is not used.

The SL command allows entry of both upper and lower case characters, as on a typewriter.

EXPLANATION

The SU command is useful for entry of assembly language mnemonics, which must all be upper case. The SL command is useful for typing long comments or text because of the greater clarity of upper and lower case text.

SYNTAX

There is a syntax error in the command.

OVERFLOW

While inserting lines into the Editor workspace, the workspace has become full. All or part of the workspace should be written to the output file. Use the W command on page 7-6.

NOT FOUND

In an F (find) or G (get) command, a character string match was not found in the field of search.

NOT SOURCE FILE

The file which was designated in a L (load) command does not have as S attribute. See File Manager, page 6-10, for a discussion of file attributes.

FILE NOT SPECIFIED

An L (load) or W (write) or N command was entered without specifying a file name and without having previously specified either an Input or Output file.

END PREVIOUS FILE?

An attempt was made to write to a new Output file without ending use of the old file (E command). Typing Y (yes) ends the previous file. Typing N or RETURN cancels the write command.

END-FILE

The Editor has reached the end of the Input file.

SAVE DATA?

An attempt was made to execute another Futuredata system program without writing the workspace to an Output file.

REPLACE THIS LINE

This message is a request for verification before replacing a string in the line displayed on the edit line (F or G command). Type Y (yes) to replace, RETURN to continue without replacement, or N to cancel execution of the command.

Section 8
Assembler

INTRODUCTION

An assembler is a computer program which converts mnemonics, chosen for the ease with which they remind the programmer of the function of an instruction, to binary instructions, chosen according to the architecture and ease of design of the computer.

The input to the Assembler is assembly source code in ASCII characters. The Assembler evaluates the input on a line-by-line basis. Each line is either an assembler statement, which results in a binary computer instruction, or an assembler directive, which directs the Assembler to perform some other operation that may or may not result in the generation of binary.

There are two categories of assembler directives. There are directives which do not result in the generation of binary. These are sometimes called pseudo-instructions, pseudo operations, or pseudo-ops; in this manual they will be referred to simply as assembler directives.

There are two kinds of assembler directives which do result in the generation of binary. There are Macros, which allow the programmer to define an assembler statement that produces many computer instructions, and there are Conditional Assembly Directives, which generate different sequences of binary depending on simple specifications at the beginning of the program. Macros and Conditional Assembly are described in the next section, Section 9. Instruction mnemonics and assembler directives are collectively called assembly language.

The Futuredata Assembler provides a single standard set of rules of use, options, and assembler directives for several microprocessors. This is an important advantage, since the programmer need only learn one assembler.

In all cases the assembler mnemonics are identical to those specified by the microprocessor manufacturer.

BEGINNING ASSEMBLER OPERATION

Type JA RETURN to begin Assembler operation. A list of Assembler options will appear on the screen.

ASSEMBLER OPTIONS

L Display a program listing on the screen. This option is affected by the T and E options.

M This option selects the use of a macro library. If the assembler does not find a macro definition on the input file, it will search the macro library file. The definitions of commonly used macros may be kept on the file, making it unnecessary to write them into programs. A macro file is originated using the Editor. The library file is read until it reaches the end of the file or encounters a statement which is not part of a macro definition. The only statements which may appear between macro definitions are printer control directives. (See page 8-18). Comments may not appear between macro definitions. Any legal statement may appear inside a definition. This feature allows the use of a source program file which has macros defined at the beginning as a macro library.

O Write a binary object file to diskette. When this option is selected, an object file is always written, even if there are errors in the assembly.

T Truncate lines of the display to 80 characters. (Printer lines are never truncated.)

The T option limits listings of the DC directive to a one line. If this option is not specified, all lines generated by the directive are output, one byte per line. This feature of the T option operates identically for printer or display.

E Only lines containing errors flagged by the assembler are displayed if L or T is specified, or printed if P, B or L is specified.

S Include a table of symbolic labels at the end of the binary object file. (During debugging, memory locations can be referenced by their label names if a symbol table is written by the assembler, selected as a Linker option, and loaded by the Debugger.)

Z This option for the Z-80 assembler only will flag all lines which contain

assembler mnemonics specific to the Z-80. Since the 8080 and 8085 instructions are a subset of the Z-80 instructions, this option is useful when rewriting a Z-80 program to run on the 8080. Lines are flagged with a "P".

P Print a program listing. This option is affected by the T and E options.

B[s][d] Output the listing to the serial port. If this option is selected, it must be the last entered. The listing is output on port 2 which is RS-232C compatible. The transmission rate can be selected by specifying the parameter s according to the following table:

0	50 Baud	6	600 Baud	C	4800 Baud
1	75	7	600	D	7200
2	110	8	1200	E	9600
3	134.5	9	1800	F	19200
4	150	A	2400		
5	300	B	3600		

The delay during carriage return is selected by specifying the parameter d. d is the number of idle characters sent after a carriage return is output to provide time to complete this mechanical operation. d may be 0 to 9. If the parameter n is not specified, it is given the value 1 when the transmission rate is 150 Baud or less and the value 4 when the rate is 300 or greater.

ENTRY OF OPTIONS

Type the appropriate letter or letters in any order without intervening blanks to select Assembler options. Then depress the RETURN key. Assembler options must be the first entry after beginning Assembler operation.

SPECIFYING ASSEMBLER FILES

After the assembler options are entered, the assembler will display the message SPECIFY INPUT FILE. Type the file name (which must have an "S" attribute) and depress the RETURN key.

M option If the M option was selected, the message SPECIFY MACRO LIBRARY will be displayed. Enter the name of the file on which the library resides. (The file must have an "S" attribute.)

O option If the O option was selected, the message SPECIFY OBJECT FILE is displayed. Enter the file name. The file may be created upon entry to the assembler by prefixing the name with N: (See page 6-4). An object file must have an "O" attribute. If the file is created on entry to the assembler, it will be given this attribute.

ASSEMBLY BEGINS

Pass 1 After the last file name is entered, assembly begins. Statements are processed in 2 passes. On the first pass, the assembler assigns values to symbolic labels and stores a symbol table. The message PASS 1 is displayed.

Pass 2 During pass 2 the assembler analyzes each statement on the input file and generates binary. If the assembler recognizes errors, they are flagged and no binary is generated for that statement.

Stopping Assembly During assembly, pressing the RETURN key causes the assembler to pause and display the message RESTART? To abort the assembly, type Y. To continue the assembly, depress the RETURN key.

Assembly language programs are composed of three types of statements: instruction mnemonics, assembler directives, and comment statements. Each statement is one line of a maximum of 80 characters.

Statements are made up of four components or fields, as shown below. Each field is separated from the next on the line by a blank space or series of blanks.

Label Field The label field of a statement may contain a symbolic name which is used to reference the statement from other statements, or which will be assigned a value by an EQU directive. This field is optional. If included, it must begin in the first character position on the line.

Operation Code Field The operation code (also called opcode) field contains either a microprocessor instruction mnemonic or an assembler directive. This field must always be present unless the entire line is a comment. See Assembler Comments, page 8-14. Operation code fields must begin in the second character position on the line or later, and must be six characters or shorter.

Operand Field This field contains additional parameters called operands associated with the mnemonic or directive in the operation code field. Operands are not always required.

Comment Field The comment field is the last field. It is not processed by the assembler but is printed or displayed in the program listing. This field allows the programmer to document the action or purpose of the statement. (Note that there is also a comment statement, which occupies an entire line. See Comment Statement, page 8-14.) If the operand field is absent, and the operation code field allows optional operands, the first character of a comment field should be a semicolon, to avoid ambiguity. A semicolon terminates assembler processing on the line in which it appears.

Statement Diagram Assembler statement fields are represented on later pages by the following diagram. The field being described is in bold.

label opcode operand comment

label opcode operand comment

A label may be invented and included on statements which must be referenced by other statements in the program. Labels are optional and should be used only where needed.

The EQU directive assigns a value to a label.

Label Name Conventions Labels must be 1 to 8 characters long and begin with a letter. Characters in a label after the first must be letters or numbers.

Labels may not be the same as the mnemonics used for microprocessor instructions, registers, or condition codes. See the appropriate Futuredata microprocessor reference manual for reserved names. Labels may also not be the same as assembler directives.

Assembler Processing During assembly, a value is assigned to each symbol.

In absolute program segments, the value assigned is the absolute address of the memory location in which the instruction will be stored.

In relocatable program segments, the value assigned to a label is the local address within the segment. (When the segment becomes part of a program, the absolute memory address of the first word of the segment is added to the local address of the label.)

When the assembler directive EQU is used, the label is assigned the value of the operand field. This directive is described on page 8-16.

Symbol Table The assembler writes each label name, the address of the label, and other information in a symbol table. Label names are represented in ASCII. Each character of a label name requires one byte of memory; short labels conserve memory space.

label opcode operand comment

The opcode is a 3 or 4 character microprocessor instruction mnemonic or an assembler directive of up to six characters. All instruction mnemonics are those assigned by the microprocessor manufacturer. Each mnemonic causes the assembler to generate one to three bytes of binary.

Refer to this manual for all information on assembler directives.

label . opcode operand comment

The operand field contains operands which may be required in instructions or assembler directives. Each operand is separated by a comma.

A blank space terminates the operand field. If a blank is inadvertently included in the field, the rest of the line after the blank will be treated as a comment.

OPERAND TYPES

Five types of operands are used in the operand field: decimal constants, hexadecimal constants, ASCII character constants, symbolic labels, an asterisk used as a symbol for the address of the first byte of the statement in which it appears, and expressions combining the previous types.

Hexadecimal Constants Hexadecimal constants are made up of the hexadecimal digits 0 to 9 and A to F. The digits must be enclosed in single quotes. An X must prefix the first quote.

Single byte constants may be 1 or 2 digits. Two byte (address) constants may be 1 to 4 digits in length. When less than the maximum number of digits are used, the constant is treated as if leading zeroes were supplied.

Examples of single byte hexadecimal constants are:

```
X'1'    (same as X'01')
X'A3'
```

Examples of two byte (address) constants are:

```
X'103'    (same as X'0103')
X'BF2A'
```

Decimal Constants Decimal constants are numbers made up of the digits 0 to 9. Single byte decimal constants may range from 0 to 255. Two byte decimal constants may range from 0 to 65,535.

ASCII Character Constants Each character of a character constant is given an eight bit value defined by the American Standard Code for Information Interchange (ASCII). The high order bit is always zero. Examples are:

'ABC' is equal to X'414243'
' ' (blank) is equal to X'20'

Symbolic Address Labels Values assigned to address labels are listed in a symbol table by the assembler during Pass 1, as is discussed under Label Field, Page 8-16.

Symbolic Address Labels During assembly, each statement is scanned and all address labels are listed in the symbol table with their assigned values. (See page 8-16 for a discussion of labels. This is accomplished during pass 2 of the assembler. During pass 2 the value assigned to a label is substituted wherever it occurs as an operand.

Asterisk Parameter (*) An asterisk used as an operand causes the assembler to substitute the value of the location counter at the first byte of the statement in which the asterisk occurs.

label opcode operand comment

RULES FOR FORMATION OF EXPRESSIONS

An operand may be an expression. Any number of terms are allowed which will fit on one line. Terms may be grouped with up to 8 levels of parentheses. commas which are not in quotes delimit the operands.

Expressions are evaluated left to right. The result of an expression is always a 16 bit quantity, although fewer bits may be required for some operands.

The terms of an expression may be of five types: decimal constants, hexadecimal constants, ASCII character constants or strings, symbolic labels, and an asterisk used to denote the address of the first byte of the statement in which it appears. These terms are described on the previous page, except for the following difference:

CHARACTER STRING OPERANDS

'1m' ASCII character constant. One or two characters in quote is evaluated as a 16 bit constant.

'string' ASCII character string of three or more characters. Each ASCII character occupies one byte. A string may be used as an operand only with relational operators (see below). If one operand of a relational operator is a string and one is another type of operand, the string is always greater. If both operands of a relational operator are character strings, comparison is done on a byte-by-byte basis.

Terms are connected with operators. The result of an operation is always a 16 bit quantity. The following operators may be used:

ARITHMETIC OPERATORS

+,- Indicate addition or subtraction.

* Multiplication.

/ Integer division. Remainder is truncated.

n.MOD.m Remainder on dividing n by m. n and m may be expressions.

LOGICAL OPERATORS

.AND. Bit by bit logical AND

.OR. Bit by bit logical OR

.NOT. Complements each bit of the following one byte operand.

.XOR. Performs bit by bit exclusive or operation (a or b but not both)

REGISTER SHIFT OPERATORS

.SHL.n Shifts the previous one-byte operand or the lower byte of a two-byte operand or expression n bits to the left. The leftmost n bits are lost. n may be an expression.

.SHR.n Shifts the previous one-byte operand or expression right n bits. This is an arithmetic right shift. The highest order bit is considered the sign bit and is not shifted or changed. If the highest order bit is a one, ones are shifted into the bit positions vacated by the right shift. If the highest order bit is a 0, zeroes are shifted into the vacated bit positions. The rightmost n bits are lost.

RELATIONAL OPERATORS

n=m Compare operator. If n is equal to m, 16 bit result is set to an integer one. If not equal, the result is zero.

n>m If n is greater than m, the result is set to an integer one. If not greater, the result is zero.

n<m Less than operator. True is integer one. False is zero.

n>=m More than or equal to. The > and = may be interposed.

n<=m Less than or equal to.

BYTE EXTRACTION OPERATORS

The high or low order 8 bits of an expression may be extracted for use as a parameter by enclosing the expression in parentheses and prefixing with H (high) or L (los). These operators are used when an expression,

which always has a 16 bit value, must be trancated to an 8 bit value. For example:

```
H(X'2E35'+2)    evaluates to  X'2E'
H(X'2E35'+2)    evaluates to X'37'
```

H(ALPHA) evaluates to the high order 8 bits of the value assigned to the symbolic label ALPHA.

Byte extraction is not allowed as a term of an expression.

OPERATOR PRECEDENCE

Operators with the highest precedence are evaluated first, from left to right. Then operators of the next higher precedence are evaluated also from left to right, and do on. The precedence is, in decreasing order:

```
Parenthesized expressions
*,/,.MOD.,.SHL.,.SHR.
+,-,unary-
=,>,<,>=,<=,><
.NOT.
.AND.
.OR.,.XOR.
```

ILLEGAL OPERATIONS

All expressions must reduce to one of the following forms: an absolute value, a relocatable value ± an absolute value, or an external value ± an absolute value.

There is one exception. An absolute expression may contain relocatable terms if the terms are in the same segment, and they are subtracted, and the result is greater than zero. Relocatable terms cannot be added.

All other operations are illegal.

COMMENT FIELDS

label opcode operand comment

The comment field starts after at least one blank space after the operand field. This field is not processed by the assembler, but is printed or displayed in the program source listing. Comments fields are used to document the action or purpose of the statement in which they appear.

A semicolon anywhere on a line, but not within quotes, also terminates assembler processing and should be used wherever there could be ambiguity. For example, if the operand field is absent, and the operation code field allows optional operands, a semicolon should be used before a comment so that the comment is not processed as an operand.

COMMENT STATEMENTS

If there is an asterisk in the first character position on a line, the entire line will be treated as a comment. Comment statements are useful for documentation which requires more space than is available in a comment field.

A line which has a semicolon as the first character (but in any character position) is also processed as a comment statement.

Comment statements which are not inside macro definitions will terminate reading of a macro library.

ORG {expression}

The ORG (origin) directive specifies the location in memory at which subsequent statement are assembled. The expression must be absolute if it is an absolute program segment and relocatable if it is in a relocatable segment.

ASEG

The ASEG directive defines the beginning of an absolute program segment. The assembler begins an absolute program segment at location zero or at a location defined in an ORG directive. After intervening relocatable segments (RSEG's), the ASEG directive will reset the location counter to one plus the address of the end of the previous absolute segment.

RSEG {rseg-name}

The RSEG directive defines a relocatable program segment. Up to 8 segments are allowed in an assembly, each identified by a unique name in the operand field. A previous RSEG may be started again where it was left off by another RSEG directive with the previous name

GLBL {label}[,label]. . .

The GLBL directive is used to list all the external references and entry points in an assembly. There may be a maximum of 255 external references.

END [expression]

The END directive terminates assembler operation. It must always be the last statement in a program.

The expression specifies a program entry point at which execution will begin.

{label} EQU {expression}

The EQU directive assigns a value to a symbolic name. The symbol in the label field is assigned the value of the expression in the operand field. The expression is evaluated during pass 1 of the assembler. The symbol name may be referenced in the operand fields of statements occurring before and after the EQU directive. However, symbols in the expression in the operand field must have been previously defined.

[label] DC {operand}[,operand]. . .

The DC directive is used to place data in memory, beginning at the value in the location counter. Multiple operands are stored in successive memory locations.

There are three ways that operands can be evaluated: 1) The value of an expression is truncated to the lower eight bits and is stored in one byte of memory. 2) An ASCII character string is stored one byte per character. The string is enclosed in single quotes. A single quote within the string is represented by two single successive quotes. 3) The 16 bit value of an expression is stored in two succeeding bytes. If the expression is enclosed in parentheses and preceded by an A, the high order byte will be stored before the low order byte. If an expression is enclosed in parentheses and preceded by a B, the low order byte will be stored ahead of the high order byte. Two-byte operands can be intermixed with single-byte operands in the same DC statement.

```
LOC     DC      H(BETA),A(ALPHA+X'23')
        DC      'ABC''D'
```

[label] DS {expression}

This directive reserves memory space. The number of memory locations reserved is determined by the value of the expression.

It cannot be assumed that the contents of the memory locations reserved is zero.

If a symbol name is used as the expression or a term of the expression, it must have been previously defined.

SPACE

This directive is replaced by a blank line in the listing. It is used to improve readability. No operands are processed.

EJE

The eject directive causes the assembler to skip to the top of the next page. It is used to improve readability. No operands are processed.

PRINT OFF

This directive suppresses printing of all following source lines. The directive itself is not printed.

PRINT ON

All source lines are listed except 1) lines in a macro, 2) lines skipped due to conditional assembly directives, 3) the conditional directives themselves. Lines are printed after set substitution takes place.

PRINT GEN

This directive operates the same as PRINT ON except that it also causes lines in a macro to be printed. Lines in a macro are printed after parameter substitution takes place. Lines are printed after set symbol substitution takes place.

PRINT ALL

This directive causes printing of all source lines including those skipped due to conditional assembly directives. Conditional assembly directives themselves are printed. Lines skipped will have no location counter value or object code printed. Lines are printed after set symbol and macro parameter substitution takes place.

INVALID LABEL
INVALID OPCODE
INVALID OPERAND
IMMEDIATE VALUE >127 OR <-128
RELATIVE JUMP OUT OF RANGE (Z-80 only)
RELATIVE JUMP TO EXTERNAL SYMBOL (Z-80 only)
RELATIVE JUMP TO DIFFERENT RSEG (Z-80 only)
DUPLICATE SYMBOL
INVALID FORWARD REFERENCE
UNDEFINED SYMBOL
EXPRESSION HAS MORE THAN 1 RELOCATABLE FACTOR
SYMBOL TABLE OVERFLOW
MORE UNPRINTABLE ERRORS
SOURCE LINE TOO LARGE - TRUNCATED
UNDEFINED SET SYMBOL
INVALID MACRO PARAMETER NAME
MISSING ENDM
MACRO DEFINITION OUT OF PLACE
MISSING ENDIF
MISSING ENDDO
EXITM OUT OF PLACE
ENDM OUT OF PLACE
OPERAND LONGER THAN 32 CHARS
OVER 255 EXTERNALS
ERROR WHILE WRITING OBJECT FILE
MACRO NESTING EXCEEDS 127
MISSING END
ENDDO OUT OF PLACE
ENDIF OUT OF PLACE
ELSE OUT OF PLACE

Section 9
Macros & Conditional Assembly

MACROS

The macro facility allows a user to define an opcode which causes a series of instructions to be assembled. For example, using the 8080, the following series of instructions will add 10 to the H and L registers, using only the A register.

```
MOV     A,L
ADI     10
MOV     L,A
MOV     A,H
ACI     0
MOV     H,A
```

If there are many such sequences in a program, it will be more efficient (in time and disk space) and less error prone to define a macro that will cause the sequence of instructions to be assembled whenever its name appears in the opcode field:

```
ADD10   MACRO   A,L
        MOV     A,L
        ADI     10
        MOV     L,A
        MOV     A,H
        ACI     0
        MOV     H,A
        ENDM
```

The macro definition is begun by the MACRO pseudo-op. The label field of the MACRO pseudo-op defines the name of the macro, in example 1, ADD10. Statements following the MACRO pseudo-op represent the body of the macro definition. These statements will be processed by the assembler when the macro name occurs in the opcode field (when the macro is "called"). The ENDM pseudo-op ends the macro definition. The macro definition must be placed at the beginning of the assembler source file, only the EJE, SPC, and PRNT pseudo-ops may occur before the macro definitions.

Macro Library All macro definitions must be placed at the beginning of the source input file. However, by specifying the M option, a second source file of macro definitions may be included in the assembly. As in the main input file, the first statement other than EJE, SPC. and print which is not in a macro definition will terminate reading of macro definitions.

Duplicate Macro Definitions If two macros with the same name are defined, the last macro definition read will be the one used. Thus macro definitions in the main source file take precedence over macro definitions in the macro library.

Macro Calls Within Macros A macro definition may include a statement which calls another (or the same) macro. These calls may be nested to any level (depending on the symbol table space available). A macro definition may not have another macro defined in its body.

EXITM Statement When processed, the EXITM statement causes immediate termination of the current or named macro. The next statement processed will be the first one following the macro call. The syntax is:

```
EXITM [macro-name]
```

Note that no label is allowed.

Macro Parameters Obviously, a macro definition like ADD10 is of limited use. How many times would you add the number 10 to the H and L registers? It is much more likely that similar rather than identical sequences of instructions occur in a program. Allowing a macro definition to have variables that may have various values when the macro is called is one way of doing this. For example, if we make the actual value added to the H and L registers a macro parameter, the user can define a macro that, when called, will generate statements that will add any number from 0 to 255 to the H and L registers:

```
ADDX    MACRO   NUM
        MOV     A,L
        ADI     &NUM
        MOV     L,A
        MOV     A,H
        ADI     0
        MOV     H,A
        ENDM
```

If the macro is called in the following way:

```
        LHLD    VALADR
        ADDX    5
        SHLD    VALADR
```

The following statements will be generated:

```
        LHLD    VALADR
        MOV     A,L
        ADI     5
        MOV     L,A
        ACI     0
        MOV     H,A
        SHLD    VALADR
```

What happens is that in the macro definition, the names of all the macro parameters are listed (separated by commas) in the operand field of the MACRO pseudo-op. When the macro is called, the actual values to be used are listed in the operand field of the calling statement (separated by commas). Then, wherever a macro parameter name appears in the body of the macro definition, preceeded by an ampersand, the actual value of the parameter is substituted in place of the ampersand and name. Note that this substitution is done character for character (up to 32 characters per parameter). The macro parameters need not be numeric. Also, the substitution may occur in the label, opcode, operand, comment, or any combination of fields. For example, for the macro definition:

```
SAVEA   MACRO   TYPE,LOC
        & TYPE  &LOC
        ENDM
```

The call:

```
SAVEA   STA,VAL
```

will result in:

```
STA     VAL
```

while the call:

```
SAVEA   STAX,D
```

will result in:

```
STAX    D
```

Macro Parameter Delimiters As stated, when a macro is called, the actual values of the parameters are listed in the operand field of the calling statement, separated by commas. However, commas and blanks may exist in a parameter if they occur between quotes. Also, there must be an even number of quotes in any parameter. The following are examples of valid parameters:

```
20
X'40'
'A,B'+'B,C'
A''C
ABC
```

Concatenating Parameters In the previous example, the value of parameter INDX, was appended in the right of the characters AB simply by writing the parameter name, preceeded by an ampersand, to the immediate right of the characters AB: AB&INDX. If, also, the user wished to append an A to the right of the value of parameter INDX, a problem would have arisen:

```
JP      AB&INDXA
```

The macro processor would have interpreted this to mean: Substitute the value for parameter INDXA. To solve this problem, the macro processor recognizes a parameter name delimiter: ! whose only function is to indicate the end of a parameter name. The correct way to append an A to the right of the value of parameter INDX is:

```
        JP      AB&INDX!A
        JP      AB00001A
```

Note that is ! appears anywhere other than after a macro parameter (or a set symbol), it will be treated as a normal character.

Literal Ampersand Since the ampersand signals the macro processor to substitute a parameter value, a special set of characters is needed to tell the macro processor that rather than substituting, an actual ampersand character is wanted. For example, if the user wants to put an ampersand into the A register, he might think to write:

```
        MVI     A,'&'
```

However, for reasons explained under Advanced Considerations, whenever a single ampersand is wanted in the generated statement, four ampersands must be written in the actual source:

```
        MVI     A,'&&&&'
```

Generating Unique Labels A macro call may generate statements with labels. For example, the following definition: (to makeD,E=absolute value of D,E)

```
ABSD    MACRO
        MOV     A,D
        ORA     A
        JP      ENDABSD
        CMA
        MOV     D,A
        MOV     E,A
        CMA
        MOV     E,A
        INX     D
ENDABSD EQU     *
        ENDM
```

The first time ABSD is called, label ENDABSD will be defined. Unfortunately, the second time ABSD is called, ENDABSD will also be defined and a duplicate definition error will result. What is needed is a way to generate a unique label each time the macro is called. The Futuredata

Macro Assembler provides this capability by pre-defining a special parameter - INDX - which will always have a unique 5 digit numeric value each time a macro is called. The macro ABSD may now be defined in the following way:

```
ABSD      MACRO
          MOV     A,D
          ORA     A
          JP      AB&INDX
          CMA
          MOV     D,A
          MOV     A,E
          CMA
          MOV     E,A
          INX     D
AB&INDX   EQU     *
          ENDM
```

Assuming that this is the only macro defined and that there are exactly two calls made, the first call defines the label AB00001 and the second call defines the label AB00002. Note that a label on the actual macro call statement takes on the current location counter value at the beginning of the call.

CONDITIONAL ASSEMBLY

These statements allow a programmer to selectively assemble statements in a source file. For example, if a programmer did not know whether the program was going to be used with a tape or disk, both the calls to the tape subroutine and disk subroutine could be included in the source file, and conditional statements used to actually assemble the one needed:

```
DEVICE    DEFG    'TAPE'
          :
          :
          IF      '&DEVICE'='TAPE'
          LHLD    TAPEFCB
          CALL    TAPEIO
          ELSEIF  '&DEVICE'='DISK'
          LHLD    DISKFCB
          CALL    DISKIO
          ENDIF
```

More often, conditional statements will be used to implement more complex macros. For example, the ADDX macro defined earlier could be expanded to add a number between 0 and 255 to the BO, DE, or HL registers:

```
ADDXY     MACRO   REG,NUM
          IF      '&REG'='BC'
REGH      DEFL    'B'
REGL      DEFL    'C'
          ELSEIF  '&REG'='DE'
REGH      DEFL    'D'
REGL      DEFL    'E'
          ELSE
REGH      DEFL    'H '
REGL      DEFL    'L '
          ENDIF
          MOV     A,&REGL
          ADI     &NUM
          MOV     &REGL,A
          MOV     A,&REGH
          ACI     0
          MOV     &REGH,A
          ENDM
```

ADDXY could be expanded further to add a number between 0 and 65537 to the BC, DE, or HL registers:

```
ADDXY   MACRO   REG,NUM
        IF      '&REG'='BC'
REGH    DEFL    'B'
REGL    DEFL    'C'
        ELSEIF  '&REG'='DE'
REGH    DEFL    'D'
REGL    DEFL    'E'
        ELSE
REGH    DEFL    'H'
REGL    DEFL    'L'
        ENDIF
NUMH    DEFL    &NUM/256
NUML    DEFL    &NUM.MOD.256
        MOV     A,&REGL
        ADI     &NUML
        MOV     &REGL,A
        MOV     A,&REGH
        ACI     &NUMH
        MOV     &REGH,A
        ENDM
```

One of the more common uses of conditional statements is to generate tables that would be long, tedious, and error prone to enter by hand. The following example generates a table that could be used to check whether a character is numeric:

```
TABLE   EQU     *
CHAR    DEFG    0
        DO      256
        IF      &CHAR<'0'.OR.&CHAR>'9'
        DC      0
        ELSE
        DC      X'FF'
        ENDIF
CHAR    DEFG    &CHAR+1
        ENDDO
```

Set Symbols Set symbols (and macro parameters) are the variables used by the conditional statements. Their value may be either numeric (0 to 65537) or a character string (0 to 32 characters long). The values are set by using the DEFG (define global) and DEFL (define local) statements.

DEFL Statement This statement is used to define (and redefine) a local set symbol. A local set symbol is only known in the macro in which it is defined. A set symbol of the same name defined in a different macro is actually a different set symbol. The syntax is:

```
{set-symbol-name}    DEFL    {expression}
```

or:

```
{set-symbol-name}    DEFL    {'string'}
```

If quotes are placed around the operand, it is treated as a character string and may be a maximum of 32 characters long. Quotes embedded in the string must be doubled. They are, however, stored as double, not single, quotes. If quotes are not placed around the operand, it is treated as an integer expression. Labels may appear in the expression only if they have been previously defined.

Note that when defining a set symbol, an ampersand must not preceed the name in the label field. When using the set symbol, an ampersand must preceed the name.

DEFG Statement This statement is used to define (and redefine) a global set symbol. A global set symbol is known in all macros unless a local set symbol of the same name is defined in a particular macro. In this case, the global set symbol will become unknown, in that particular macro only, as soon as the like named local set symbol is defined. The syntax is:

```
{set-symbol-name}    DEFG    {expression}
```

or:

```
{set-symbol-name}    DEFG    {'string'}
```

If quotes are placed around the operand, it is treated as a character string and may be a maximum of 32 characters long. Quotes embedded in the string must be doubled. If quotes are not placed around the operand, it is treated as an integer expression. Labels may appear in the expression only if they have been previously defined.

Note that when defining a set symbol, an ampersand must not preceed the name in the label field. When using the set symbol, an ampersand must preceed the name.

IF Block An IF block begins with an IF statement and ends with an ENDIF statement. IF blocks may be nested within IF blocks or DO blocks to any level.

IF Statement The IF statement begins an IF block. It may have an optional name in the label field which may be referred to in the EXITIF statement. If the expression in the operand field of the IF statement is non-zero, the statements following the IF statement up to the first ELSE, or EXITIF statement at the same nesting level will be processed. If the expression is zero, the statements following the IF up to the first ELSEIF, ELSE, or ENDIF statement at the same nesting level will be ignored. The syntax is:

```
[if-block-name]   IF      {expression}
```

ELSEIF Statement The ELSEIF statement is used in conjunction with an IF statement to test an alternate condition without going to a deeper nesting level. If the expression in the IF statement was 0 and the expressions in all previous ELSEIF statements at this nesting level were 0, and the expression in this ELSEIF statement is non-zero, statements up to the next ELSEIF, ELSE, or ENDIF statement at this nesting level will be processed. The syntax is:

```
ELSEIF {expression}
```

Note that no label is allowed.

ELSE Statement The ELSE statement is used in conjunction with an IF statement to indicate the last alternative. It is identical to:

```
ELSEIF 1
```

That is, if the expressions in the IF statement and all subsequent ELSEIF statements at this nesting level are 0, the statements after the ELSE statement up to the closing ENDIF statement are processed. The syntax is:

```
ELSE
```

Note that no label or operand is allowed:

EXITIF Statement The EXITIF statement when processed will cause all statements up to the closing ENDIF statement in the named or current IF block to be ignored. The syntax is:

```
EXITIF [if-block-name]
```

Note that no label is allowed.

ENDIF Statement The ENDIF statement terminates an IF block. The syntax is:

```
ENDIF
```

Note that no label or operand is allowed.

DO Block A DO block begins with a DO statement and ends with an ENDDO statement. It causes repetitive assembly of the statements within the block. DO blocks may be nexted within IF blocks or DO blocks to any level.

DO Statement The DO statement begins a DO block. It may have an optional name in the label field which may be referred to in the EXITDO and NEXTDO statements. The expression in the operand field is evaluated ONCE at the entry to the DO block and is stored as the DO COUNT - the number of

times the statements within the block are processed. The syntax is:

```
[do-block-name]    DO    [expression]
```

If the expression is omitted, the block will be processed 65538 times (essentially indefinitely).

EXITDO Statement The EXITDO statements, when processed, causes the assembler to immediately terminate processing statements in the current or named DO block and begin at the first statement after the closing ENDDO statement. The syntax is:

```
EXITDO  [do-block-name]
```

Note that no label is allowed.

NEXTDO Statement The NEXTDO statement, when processed, causes the assembler to immediately begin processing the next iteration of the current or named DO block. That is, if this is not the last iteration, the next statement processed will be the first statement after the DO statement. The syntax is:

```
NEXTDO  [do-block-name]
```

Note that no label is allowed.

ENDDO Statement The ENDDO statement terminates a DO block. The syntax is:

```
ENDDO
```

Note that no label or operand is allowed.

SUBSTR Statement The SUBSTR (substring)statement assigns a part of a string to a set symbol. If the set-symbol has not been previously defined, a new local set-symbol will be defined. The syntax is:

{set-symbol-name} SUBSTR {expression-a},{expression-b},{'string'}

expression-a defines the beginning character position of the sub-string. The first character is position 1. expression-b defines the length of the substring. If expression-b is 0, the substring will begin with the character defined by expression-a and continue to the end of the string.

LENGTH Statement The LENGTH statement assigns the length of a string to a set symbol. If the set-symbol has not been previously defined, a new local set-symbol will be defined. The syntax is:

{set-symbol-name} LENGTH 'string'

ADVANCED CONSIDERATIONS

Each source line is scanned twice before processing for ampersands which signal set symbol or macro parameter substitution. During each scan any set symbol names preceeded by ampersands have their values substituted for the ampersand and name. Any doubled ampersands are replaced by a single ampersand. This allows the following capabilities:

Subscripted Set Symbols The following statement will define a set symbol whose name is based on the value of another set symbol:

```
A&1         DEFL    'A'
```

If &I has the integer value 4, the set symbol A00004 will be defined to have the value A. The following statement uses the set symbol:

```
            MVI     B,'&&A&I'
```

On the first scan, the && is replaced by & and &I is replaced by 00004 leaving:

```
            MVI     B,'&A00004'
```

On the second scan, &A00004 is replaced by A leaving:

```
            MVI     B,'A'
```

By varying the value of the set symbol I, set symbols may be defined and referenced which are indexed using I as a subscript.

Indirect Set Symbols The following statements will define a set symbol whose value is the name of another set symbol:

```
A           DEFG    'ABC'
B           DEFG    'A'
```

The following statement will use the set symbol B as an indirect reference to the value of set symbol A:

```
            IF      '&&&B'='ABC'
```

On the first scan, the first two ampersands will be replaced by a single ampersand and &B will be replaced by A leaving:

```
            IF      '&A='ABC'
```

On the second scan, &A will be replaced by ABC leaving:

```
IF      'ABC'='ABC'
```

Section 10
Program Segment Linker

The Linker is a computer program which links relocatable program segments (RSEG's).

Diskette files containing assembled RSEG's are input to the Linker. Memory locations are assigned to each RSEG and to each address label in an RSEG which has been declared global by a GLBL assembler instruction. Since one or more RSEG's may reference each global address label, assigning a common memory location to global address labels of the same name causes the RSEG's to be linked together.

The primary output of the Linker is diskette file which contains absolute binary computer instructions and data which may be loaded into memory and executed as a single program.

The Linker may also display or print a reference list, a memory map, and error diagnostics.

The Linker responds to two kinds of commands: control options and input commands.

COMMAND FILES REDUCE KEYBOARD TIME

Commands to the Linker may be made from the keyboard or a command file. If complex Linker operations are to be performed, it is suggested that a command file be generated using the editor. A command file allows easy modification and re-execution of commands without entering commands again at the keyboard. See Command Files, section 5.

BEGINNING LINKER OPERATION

Type JL RETURN to begin Linker operation. A list of Linker Control Commands will appear on the display.

CONTROL OPTIONS

Option Letter	Action Taken by Linker
O	Write an absolute binary object file to diskette. This option must be selected if the linked RSEG's are to be executed. This option may be omitted if the Linker is being run only to get display, printer, or serial port output.
D	Only RSEG's which are specifically named in the command file or by keyboard entry are input to the Linker; others are deleted. If D is selected, unspecified RSEG's are deleted from both the binary and display output.
S	The symbol tables (which may be placed at the end of each RSEG by the assembler) are written at the end of the absolute binary object file. These tables are required for symbolic debugging. The O option must also be selected when S is specified.
L	Display the memory map and reference list.
P	Print the memory map and reference list.
B[speed][delay]	Output the memory map and reference list to the serial port. Speed is a number designating baud rate and delay is a number designating the number of idle characters transmitted after each line. See Utilities, Section 14. This must be the last entry.

PURPOSE

Linker control options specify combinations of input and output available to the user.

EXPLANATION

Control options may be entered only immediately after the beginning Linker operation. Each option is selected by typing the appropriate letter. Multiple options may be selected by typing the corresponding letters in any order without intervening blanks.

COMMANDS

	Explanation
input-file-name [input-file-name] ⋮	As many input files as needed may be specified, one per depression of the RETURN key.
[object-file-name]	One object file must be entered if the O control option was selected.
#ORG {absolute-address}	Specify the absolute address of the start of the first RSEG which will be entered.
{rseg-name-a}[,rseg-b] [rseg-name-c] ⋮	Then specify a list of RSEG's, as many as desired, which will be loaded in the order given starting at the address in the #ORG statement.
#ORG {absolute-address} rseg-name-d ⋮	More starting addresses, each with a list of RSEG's, may be specified.
#END [global-name]	global-name is used as the entry point of the program. If none is specified, the first byte of the first RSEG will be the entry point. Only one #END command can be used.

Notes:

1) If Linker control option D is not selected, all RSEG's which were not specified in #ORG commands are included after the last named RSEG in both the binary and display output.
2) If there is more than one RSEG of the same name in the input files the first one encountered by the Linker will be used.
3) It is possible using #ORG commands to define the origin of an RSEG at the location of a previous RSEG. If this is done, the overlaid RSEG will be flagged by an "O" in the length column of the memory map.

PURPOSE

Linker input commands specify the diskette files on which relocatable program segments (RSEG's) have been stored, the names of the RSEG's which are to be linked, the address at which the RSEG's are to be loaded into memory, and the entry point at which execution of the linked segments will begin after loading.

EXPLANATION

Input After the Linker Control Options are entered, the Linker will prompt: SPECIFY INPUT FILE. Enter the file name and depress the RETURN key.

The Linker will display the names of the RSEG's on the file and their lengths.

Once a file is entered, the diskette containing it may not be removed during Linker operation.

The Linker will again prompt SPECIFY INPUT FILE. If another file is to be included, proceed as before, if not, depress the RETURN key.

If the "O" option was selected, the Linker will prompt SPECIFY OBJECT FILE. Type the file name and depress the RETURN key. The Linker will then prompt LINKER INPUT.

Output After the #END command is entered, the Linker links all the program segments, outputs selected information, displays the entry point, and displays the message: FUNCTION COMPLETED.

This is an example of a Linker memory map:

```
FUTUREDATA LINKAGE EDITOR

ADDR  RSEG      FILE        LENGTH

0400  KEYB      KEYB.R       000B
040B  COUNT     COUNT.R      0009
0414  INC       INC.R        0005
1000  TEMP      COUNT.R      0001
```

1) Memory locations of the RSEG's are listed in the order in which they were input to the Linker. If the operands of the #ORG commands were input in ascending order then the listed memory locations will also be in ascending order.
2) The RSEG name, the name of the file from which the RSEG was taken, and the RSEG memory length in hexadecimal are also listed.
3) If an RSEG was deleted (control option D was specified) the name of the RSEG will appear in the memory map but the address will be flagged with a "D".
4) If an RSEG is overwritten by another RSEG, the overwritten RSEG will be flagged with an "O" in the memory map. (See Linker Input Commands.)

This is an actual example of a Linker reference list:

```
FILE        RSEG        ADDR LENGTH
KEYB.R      KEYB        0400 000B

            GLOBALS
            KEYB        0400


FILE        RSEG        ADDR LENGTH
COUNT.R     COUNT       040B 0009
            TEMP        1000 0001

            GLOBALS
            COUNT   040B      COUNT1   040B      LIMIT    1000


FILE        RSEG        ADDR LENGTH
INC.R       INC         0414 0005

            GLOBALS
            INC     0414      INCR     0414

ENTRY POINT 0000
```

1) The Linker reference list shows each disk file from which RSEG's were input,
2) the name of each RSEG,
3) the hexadecimal memory address of the beginning of each RSEG,
4) the hexadecimal length of the RSEG.
5) The list also shows global address labels with the absolute memory address which was assigned to each label.
6) The last line of the reference list is the entry point address at which program execution will begin.

NOT A RELOCATABLE FILE - The Linker input file was not created by the Futuredata Relocating Assembler or the "R" attribute has been changed using the File Manager

PARM ERR. . . RESPECIFY - Syntax error in the Linker input.

(label) **DUPLICATE GLOBAL IN (filename) - The first occurrence of a global label is used for address references. All additional definitions are flagged as an error.

(label) **UNRESOLVED REFERENCE IN (filename) - The external reference was not found in the global symbol table.

**DELETED RSEG REFERENCED IN (filename) - An RSEG which was not included is needed to resolve address references.

**RELOCATION ERROR IN (filename) - Input file was not correctly assembled with the Futuredata Relocating Assembler.

**TABLE OVERFLOW - The Linker needs more memory.

**SYMBOL TABLE NOT FOUND IN (filename) - The symbol table was not included when the program was assembled.

**SEQUENCE ERROR IN (RELOCATABLE FILE NAME) - records in (relocatable file name) are not in proper order. Reassemble.

Section 11
Symbolic Debugger

INTRODUCTION

The Futuredata Debugger is called symbolic because memory locations may be referenced by the symbolic address labels used in the program being debugged.

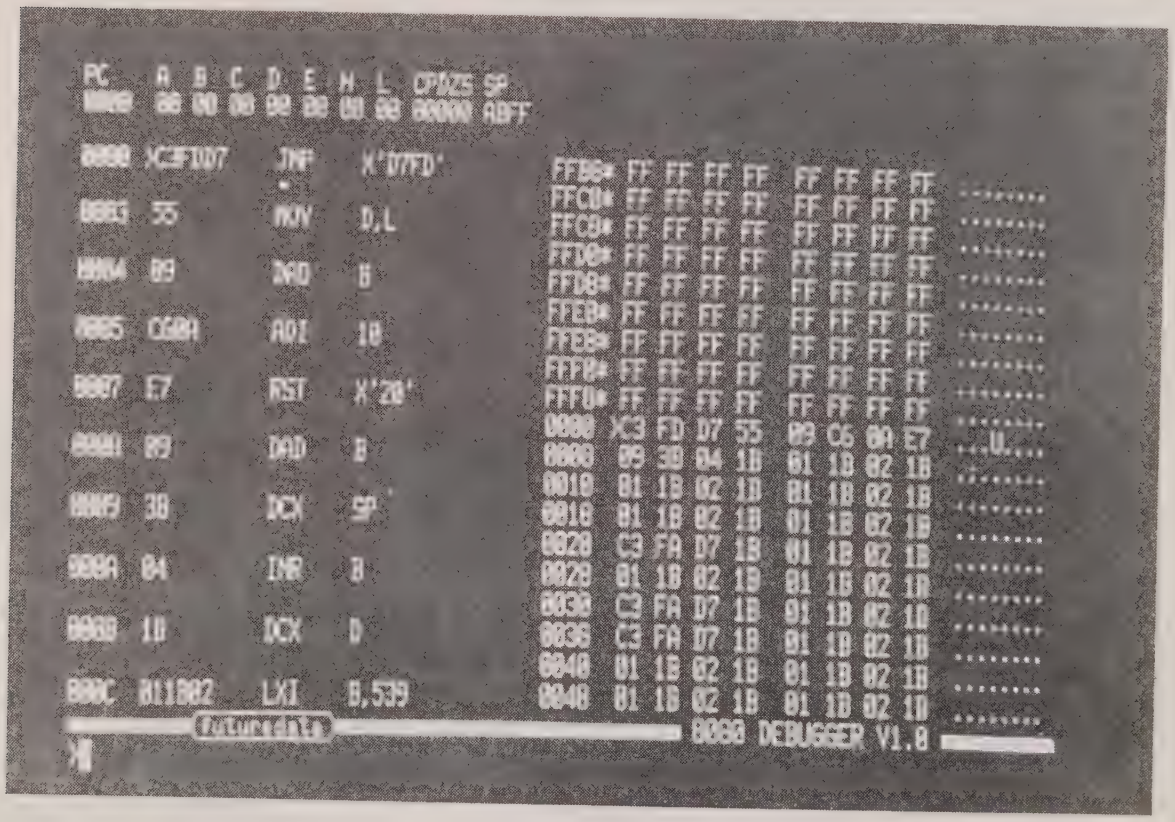
The Debugger is an extremely powerful tool for finding and correcting errors in a program. The Debugger allows the user to see and change the contents of memory and registers. A program may be executed beginning at any point at processor speed or may be executed one instruction per keystroke. The user may set breakpoints which stop execution and return control to the keyboard. Trace execution allows the user to view the state of the program counter, registers, and status bits for the 20 instructions executed prior to a breakpoint. Memory addresses may be referenced by the address labels used in assembly language source programs. Sections of memory may be write-protected.

Debugger Information Specific to a Microprocessor Information on debugging which is microprocessor dependent may be found in the microprocessor reference manual. For example, for the 8080 further information is in the Debugger section of the Futuredata 8080 Reference Manual.

BEGINNING DEBUGGER OPERATION

Type JD [RETURN] to begin debugger operation.

This is an example of the debugger display for the 8080:



Register Display The first line of the display shows the letters assigned by the manufacturer of the microprocessor to the 8080 internal registers.

The second line displays the contents in hexadecimal of the registers and program status byte. These first two lines vary depending on the microprocessor since the registers and letter designations vary.

The rest of the display is split into two halves which are separately controlled by debugger commands.

Disassembly Display, left side. The left half shows 10 microprocessor instructions.

The first column on the left shows the hexadecimal memory address of the instruction. If a multibyte instruction is used, the address of the

first byte is displayed. The address is suffixed with an * if it is write protected, or a + if it is in the user system during emulation.

The second and third columns show the assembly mnemonic assigned by the microprocessor manufacturer to that instruction.

Disassembly is performed as though memory contained program. Since disassembly may start at any byte in memory, and the memory locations may contain data rather than program, the disassembly display may be meaningless. It is up to the user to position the left half of the display so that disassebmly starts at the first byte of an instruction.

Memory Map, right side. The first column of the right side of the display lists the hexadecimal address of the first of eight memory locations on each line. If a location in memory is write protected it is suffixed with an asterisk. If, during emulation, a location in memory is placed in the user system, it is suffixed with a plus.

The next eight columns are the contents of memory in hexadecimal. The first column is the contents of the addresses shown. The addresses of the others may be obtained by counting.

The last column is the ASCII representation of the contents of each of the locations in the memory map. This feature is useful if the contents of the memory displayed is alphabetic data. If a byte does not contain a printing ASCII character a dot is displayed.

Memory Pointers. These are two pointers, one on each side of the display, which point to the displayed contents of memory. These memory pointers indicate the byte at which execution would begin after an execute or single step command. The cursor address is also used as input by 3 other commands.

Command Entry Cursor There are two more pointers on the command line. The blinking rectangle command entry cursor may be positioned in front of either by depressing the tab key. When the blinking cursor is on the left side, commands may be entered which affect only the left half of the display. When the blinking cursor is on the right side, commands affect that side. The side on which the cursor is located is called the active side of the display.

COMMAND

L{file-name}[,[offset][,symbol-table-address]]

file-name is the name of the absolute object file.

offset is a constant or expression which specifies the number of memory locations to be added to the load address given in the object file. If not specified, the offset value is zero. This parameter is used in programming EPROM's. (See Section 14, EPROM programming.)

symbol-table-address is a constant or an expression which specifies the beginning address at which the program symbol table is to be loaded. Notice that if this parameter is specified, but the offset parameter is not, the table parameter must be separated from file-name by two commas. If symbol-table-address is not specified, the table will not be loaded.

Note: This command will set the program counter to the entry point of the loaded program.

PURPOSE

This command loads absolute binary object programs so that they may be examined, changed, and executed using the Debugger.

EXPLANATION

See page 11-20 for rules for formation of expressions. Symbols from a previously loaded symbol table may be used as terms of an expression in this command.

EXAMPLES

The following are legal forms of the Load command:

```
LPFILE,10B+F8,10B+F8+3000
LCOUNTER,,B0B8-A0F  (no offset param)
LCALC,1000  (no symbol table)
```

Symbolic debugging requires that a symbol table which was generated by the Assembler (S option), and output to a diskette file by the Linker (S option), be loaded into memory by the Debugger (symbol-table-address parameter).

On completion of loading, the Debugger displays the hexadecimal length of the symbol table. If there is insufficient memory for the symbol table, or if the memory into which it would be loaded is write-protected, the message PARTLY LOADED is displayed. Symbols which were loaded can be referenced. In order to load the complete symbol table, it is necessary to add more memory or specify a lower symbol table address.

To determine which symbols were loaded, position the display at an address near the end of the symbol table. The names of the symbols are shown on the right side of the display as ASCII characters. Each entry in the symbol table occupies 4 bytes past the last character of the symbol name. (See the Assembler, Section 8, for a complete description of the symbol table.)

COMMAND

TAB Successive keystrokes swap the command cursor left and right.

PURPOSE

This command selects which half of the display the next command will affect.

EXPLANATION

The Debugger display is formatted into two halves. Commands operate on each half independently. The left half displays assembler mnemonics obtained by disassembling the program in memory. The right half displays memory addresses and the contents of each address.

COMMAND

D{expression}

expression may be a constant, an arithmetic expression, an indirect address, a relative address, a symbolic reference or a combination or the above.

D[$]

This form of the command returns the previous display to the screen.

PURPOSE

This command displays the contents of memory both in hexadecimal (right side of display) and in microprocessor mnemonics obtained by disassembly (left side).

EXPLANATION

For rules for formation of expressions, see page 11-20.

COMMANDS

[↑] advance 1 line

[↓] back up 1 line

[→] advance 1 byte

[←] back up 1 byte

PURPOSE

These keys change the position of the memory pointer by one byte or one line (eight bytes).

EXPLANATION

The side of the display which is affected is indicated by the position of the command cursor.

COMMAND

S{constant}[,constant]. . .

The constants are stored beginning at the memory pointer address, one per location.

constant is a one or two digit hexadecimal number or a single ASCII character surrounded by single quotes. If a single digit is used, the high order four bits stored will be zeroes.

PURPOSE

This command stores data entered at the keyboard directly into memory.

EXPLANATION

The side of the display at which data is stored in memory is indicated by the position of the command cursor.

EXAMPLE

```
S1E,'A','B'
```

This example stores the hexadecimal constant 1E in the address indicated by the memory pointer. The eight bit ASCII representation of the letters A and B are stored one in each of the two succeeding memory locations.

COMMAND

Z{reg=constant}[,reg=constant]. . .

reg may be any register shown at the top of the display, except the program counter.

If reg is an 8 bit register, constant may be a one or two digit hexadecimal number or a single ASCII character surrounded by single quotes. If a single hexadecimal digit is specified, the high order four bits stored will be zeroes.

If reg is a 16 bit register, constant may be a one to four digit hexadecimal number or one or two ASCII characters surrounded by single quotes. If less than four hexadecimal digits or only one ASCII character is specified, the high order bits stored will be zeroes.

PURPOSE

This command stores data entered at the keyboard directly into a register.

EXPLANATION

If an attempt is made to set the program counter, the message SYNTAX is displayed and no action is taken.

EXAMPLE (8080 microprocessor)

The command

```
ZSP=A100,B='H',C=3
```

stores the hexadecimal number A100 in the stack pointer, a 16 bit register. It also stores the hexadecimal number 48, which is the hexadecimal representation of the character H in ASCII, in the B register. It stores hexadecimal 03 in the C register.

COMMAND

F[constant][,constant]. . .

constant is a one or two digit hexadecimal number or a single ASCII character surrounded by single quotes. If a single digit is used, the high order four bits will be zeroes.

If no parameters are specified, the previous constant or constants specified in an F command is used.

PURPOSE

The F command searches through memory, starting at the address of the memory pointer on the active side of the display, for a match between the constants specified and a byte or series of bytes in memory.

EXPLANATION

Each constant occupies one byte. A match occurs when the bytes specified in the F command are identical to a series of bytes in memory. When a match is found, the F command positions the memory pointer at the first byte of the match.

The F command begins searching for a match at the memory pointer address of the active side of the display.

Unless a match is found, the command searches to the end of memory (FFF), begins searching again at the beginning of memory (000), and continues to the memory pointer address, where is stops.

SET BREAKPOINT COMMAND

BS{n}

n is an integer between 0 and 4.
If n = 0, the hardware breakpoint will be used.

PURPOSE

This command sets a breakpoint at the cursor address.

DISPLAY BREAKPOINT COMMAND

BD{n}

n is an integer between 0 and 4.

PURPOSE

This command positions the memory cursor at the address of the nth breakpoint.

EXPLANATION

See page 11-14 for an explanation of breakpoints.

RESET BREAKPOINT COMMAND

BR

PURPOSE

This command removes the breakpoint at the address indicated by the memory pointer and restores the former instruction. If there is no breakpoint at this address, the message NOT ACTIVE is displayed and no action is taken.

CLEAR ALL BREAKPOINTS

BC

PURPOSE

All breakpoints are removed and former instructions restored.

EXPLANATION

See page 11-14 for an explanation of breakpoints.

A breakpoint is a location in a program being debugged at which execution is stopped and control is returned to the Debugger. Breakpoints are useful for splitting a program into pieces which may then be executed separately. This makes debugging a complex program a much more manageable job.

If n=0 in the breakpoint set command, a hardware interrupt is used to return control to the Debugger. This is a hardware breakpoint.

If n is 1 to 4, a microprocessor interrupt instruction is used to return control to the Debugger. This is a software breakpoint. The numbering serves to uniquely identify each breakpoint.

When a software breakpoint is set, a microprocessor interrupt instruction (hexadecimal F7 for the 8080, 3F for the 6800) is stored at the memory location of the breakpoint. This instruction replaces one of the instructions in the program, but since the last instruction of the piece of the program being debugged is just before the breakpoint, the change does not affect execution.

The instruction which was in the memory location occupied by a software breakpoint is automatically restored when the breakpoint is cleared.

When a breakpoint returns control to the Debugger after execution, the memory pointer is positioned one byte after the breakpoint.

To resume execution at the last instruction in the program which was not executed, it is necessary to back up the memory pointer one byte, clear the breakpoint, and enter an E (execute) command.

EXAMPLE

If a breakpoint is set at the first byte of a subroutine call instruction, program execution will stop and control will be returned to the debugger instead of calling the subroutine. It is then possible to check the parameters that are to be passed to the subroutine and verify that they are correct.

Then a breakpoint may be set at the subroutine's instruction, the call instruction restored by clearing the former breakpoint, and execution begun at the call instruction. Execution will stop at the new breakpoint, at which time the output of the subroutine may be verified. Debugging continues throughout the entire program in this manner.

EXECUTE PROGRAM COMMAND

E[expression]

Execution starts at the address specified by the value of the expression. If the expression is omitted, execution is begun at the memory pointer address of the active side of the display. (See explanation below.)

E$

Execution starts at the address specified in the program counter.

EXECUTE SINGLE INSTRUCTION (SINGLE STEP)

STEP

A single instruction at the cursor address is executed.

EXPLANATION

See page 11-20, for rules for formation of expressions.

The memory pointer is moved to the next address indicated by the program counter, which is the address of the next instruction to be executed.

If the executed instruction was a branch, jump or call, the display may show a totally different area of memory than before execution. Type D$ to return to the former display.

For a discussion of starting execution when the cursor is positioned at a breakpoint, see Page 11-14.

The display goes blank during execution. This is not noticeable if execution requires a short period of time.

COMMAND

W{file-name}{,start-addr,end-addr}[,start-addr,end-addr]...[,entry-addr]

All addresses are expressions or hexadecimal constants.

The specified memory addresses will be written to the file filename in absolute object format.

If entry-addr is omitted, the first start-addr will be used as the entry point address.

PURPOSE

Any series of memory locations may be written to a diskette file as absolute binary using this command.

EXPLANATION

See page 11-20 for rules for formation of expressions.

The contents of memory is not affected by this command.

If N: is prefixed to the file name, the file will first be created.

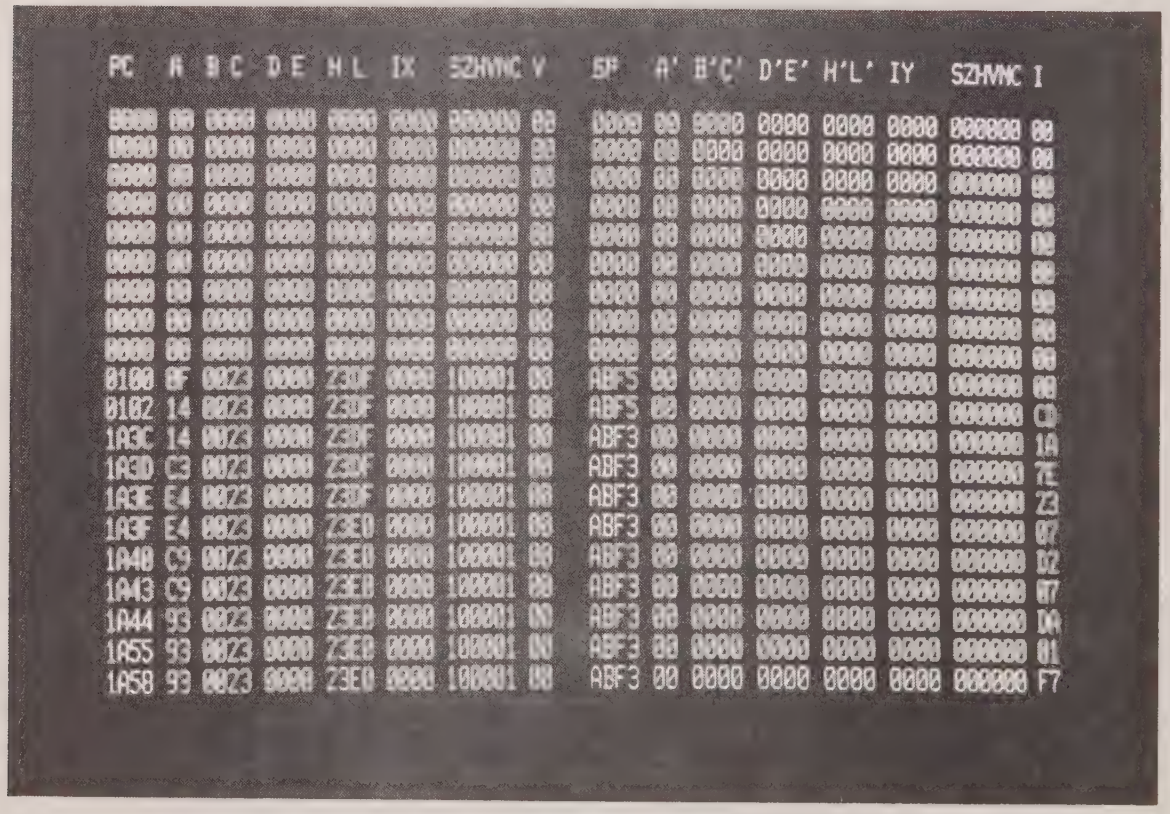
COMMAND

TR

PURPOSE

This command displays the data saved in a T (Trace Execution) command.

EXAMPLE (Z-80)



Each line of this photograph shows the contents of the registers of a Z-80 after the execution of one of twenty instructions prior to a breakpoint. The letter register designations at the top are those of the manufacturer. The last set of data or "trace" taken is at the bottom.

COMMAND

X

Switches protection on or off for the 1024 (decimal) block of memory locations in which the memory pointer of the active side of the display is located.

PURPOSE

This command prevents writing to memory. Write protection assures that a faulty program will not write into memory locations which contain program or data meant only to be read.

Many debugger commands allow the use of expressions as parameters. The following elements may be combined to make an expression:

{digit}[digit][digit][digit] hexadecimal constant, 1-4 digits

'character' ASCII constant (8 bits per character)

+ or - indicates binary addition or subtraction

#[file-name:][symbol] symbolic address

Suffixes

* causes the Debugger to treat the previous term of the expression as an indirect address.

% causes the Debugger to treat the previous term of the expression as a relative address.

EXPLANATION

Terms may be written in any order. Each expression must evaluate to a 16 bit memory address.

ASCII Constants ASCII constants must be enclosed in single quotes.

Symbolic Addresses Memory locations may be referenced by the address labels which were used when the program was written. To use this feature, the symbol table must have been loaded into memory. (see Loading for Symbolic Debugging, page 11-5.)

file-name may be specified to distinguish between identical address labels in different program segments which are in different files.

If a symbol is referenced which is not in the symbol table, the Debugger displays the message: UNDEFINED SYMBOL.

Suffixes An * suffixed to a term evaluates to the contents of the memory location specified by the term.

A % suffixed to a term evaluates to the contents of the memory location specified by the term plus the contents of the first memory location after the one specified by the term. This suffix is meant to be used with the Z-80 relative branch instruction. However, it always operates as described.

SYNTAX

There is a syntax error in the command.

NOT FOUND

The F (find command) did not find a match after searching all of memory.

NOT IN USE

1) An attempt was made to display a numbered software breakpoint which is not in use.

2) An attempt was made to reset the hardware breakpoint. It is not in use.

3) An attempt was made to reset a software breakpoint. The memory pointer of the active side of the display was not positioned at a breakpoint.

SP NOT IN RAM

A program will not be executed unless the stack pointer is located in RAM.

NOT OBJECT FILE

The file being read by a L (load) command, or the file bring written by a W (write) command does not have the "O" attribute designating it as a binary object file. See File Manager, page 6-10 for a discussion of file attributes.

UNDEFINED SYMBOL

An expression used as a parameter of a command contains a symbol which is not in the symbol table.

SYMTAB LENGTH = xxxx PARTLY LOADED

There is insufficient room in memory for the symbol table.

NAME ERR

A file name was entered with incorrect syntax.

Section 12
Emulator

INTRODUCTION

The Emulator is a hardware feature with which the AMDS can emulate a microprocessor. A connector on the end of a cable attached to the AMDS is plugged directly into a microprocessor socket. The powerful capabilities of the AMDS can then be used to aid hardware development.

Initially the AMDS is used to debug the software. Then, with the software in the AMDS, the user may command the AMDS to switch timing control to the clock in the hardware prototype. After proper operation of the prototype clock is verified, control lines and I/O can be switched from the AMDS to the prototype for debugging and verification of operation.

The level of emulation is decreased bit by bit until all functions are in the prototype. Then the AMDS plug is removed from the microprocessor socket and a microprocessor is substituted. This step-by-step hardware debugging is extremely effective and efficient.

EMULATOR REFERENCE MANUAL

For a complete discussion of the Emulator and emulation techniques, see the Futuredata Emulator Reference Manual.

BEGINNING EMULATOR OPERATION

Emulator commands are available during Debugger operation. The AMDS must have emulator hardware installed to use this function.

IMPORTANT NOTE

The AMDS automatically sets the stack pointer to point to a suitable location in memory. The user must set the stack pointer in a stand-alone prototype so that it points to an available area in RAM.

COMMAND

M[mode][mode]. . .

mode may be any combination of the following:

C Enables the prototype clock. This mode causes the AMDS to switch from the AMDS internal clock to the prototype clock.

D Enables direct memory access. This mode causes the AMDS to suspend processing in response to prototype direct memory access requests so that the prototype can gain access to the AMDS system bus.

8080, 8085 Switches HOLD and HLDA lines.

Z-80 Switches BUSRQ and BUSAK lines.

6800, 6802 Switches TSC, HALT and BA lines.

I Enables prototype control lines.

Z-80 Allows the prototype to control INT-, NMI-, RESET-, WAIT-, and to respond to I/O reads and writes. (In this mode the Z-80 will not generate any internal I/O requests.)

6800, 6802 Allows the prototype to control INTR-, NMI-, and RESET-.

M Z-80 Enables prototype memory map.

P 6800, 6802 Disables AMDS I/O when running prototype. This mode is especially useful in disabling the memory protect registers so that the prototype program cannot clear the protect registers and then clear memory. (Not required in 8080 and Z-80 because of separate I/O lines.)

E Full Emulation mode.

8080, 8085 Enables clocks, RESET, READY, and INTERUPT lines and direct memory access.

6800, 6802 Enables clocks, NMI-, INTR-, RESET-, TSC-, HALT-, DMA, and memory map.

Z-80 Enables clocks NMI-, INT-, RESET-, WAIT-, DMA, I/O requests, and memory map.

Unless otherwise specified in an M command, the AMDS clock will be used, the system will not respond to external reset or control lines.

PURPOSE

The M (mode) command controls the mode or level of emulation of the AMDS Emulator.

EXPLANATION

See the Fururedata Emulator Reference Manual.

ADDENDUM TO PREVIOUS PAGE, MODE COMMAND

mode may also be one of the following:

U 8080,8085 Enables the prototype RESET, READY, and INTERRUPT lines.

6800, 6802 Enables the prototype clock and the memory map command. The memory map is under the control of the U command (See page 12-4).

R Disables AMDS display refresh for use with protoype systems which make DMA requests. This mode can only be used when the AMDS is equipped with a high speed static RAM.

COMMAND

U{addr}[,mask]

addr is an expression which defines the beginning of a 2048 byte region.
mask is a hexadecimal constant. Each bit represents a 256 byte block of the 2048 byte region to be mapped.

PURPOSE

This command specifies which 256 byte blocks of memory will be in the prototype and which will be in the AMDS.

EXPLANATION

If addr is not on a 2048 byte boundary the message NOT ON 2K boundary will be displayed.

Section 13
EPROM PROGRAMMING

INTRODUCTION

The Futuredata AMDS EPROM programmer programs four different UV-erasable memories, the 2704, 2708, 2758, and 2716. Commands are provided to check that an EPROM is fully erased, to program an EPROM, to input EPROM data into the AMDS memory, and to verify that data in the AMDS memory is the same as data in an EPROM.

BEGINNING EPROM PROGRAMMING

EPROM Programming commands are available during Debugger operation. EPROM Programming requires that Emulator hardware be installed in the AMDS.

CHECK FOR EPROM EMPTY

C[type][,length]

type is the EPROM type. It may be 2704, 2708, 2758, or 2716. If type is omitted, 2708 is assumed.

length is the number of bytes beginning at byte zero which will be checked. If omitted, the entire EPROM is checked.

EXPLANATION

If an EPROM being checked is empty, the message EPROM IS EMPTY is displayed. Otherwise the message NOT EMPTY AT XXXX appears, where XXXX is the four digit hexadecimal address of the first location not empty. An EPROM is empty if all bits are high.

PROGRAM EPROM

P[type][,length]

type is as defined above.

length is the number of bytes, beginning at byte zero, which will be programmed. If omitted, the entire EPROM is programmed.

Data from the AMDS memory will be transferred beginning at the memory pointer address of the active side of the display.

EXPLANATION

The EPROM is checked after it has been programmed. If there is an error, the message MISMATCH AT XXXX is displayed, where XXXX is the hexadecimal EPROM address of the first byte which does not match.

INPUT DATA COMMAND

I[type][,length]

type is the EPROM type. It may be 2704, 2708, 2758, or 2716. If type is omitted, 2708 is assumed.

length is the number of bytes beginning at byte zero of the EPROM which will be input to the AMDS.

Input data is stored in AMDS memory beginning at the memory pointer address of the active side of the display.

VERIFY DATA

V[type][,length]

type is as defined above.

length is the number of bytes in the EPROM to verify. If omitted, the entire EPROM is verified.

Data in the EPROM is verified against data in the AMDS memory beginning at the memory pointer address of the active side of the display.

EXPLANATION

If there is a mismatch, the message MISMATCH AT XXXX is displayed, where XXXX is the four digit hexadecimal EPROM address of the first byte which does not verify.

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